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REPORT No. 3

(Great Britain, Northern Ireland, India, Dominions, Protectorates and Colonies)

ON THE QUESTION OF SHUNTING YARDS (SUBJECT III FOR DISCUSSION AT THE TENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION), (1)

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Figs. 1 to 15, pp. 881 to 903.

INTRODUCTION.

In the development of railways few aspects are more important and engage more study from Railway Operating Officers than the most effective lay-out and organisation of Freight Train Marshalling Yards.

With the growth of communities and expansion of industrial and commercial activities, conditions rapidly change and to such an extent as to make insistent demands for increased and quicker transportation facilities. Speed has become more than ever an essential requirement.

Co-related to these demands is the necessity for Railway Administration to respond to them in the most economically efficient manner, and in this direction, in the case of railway marshalling yards, the provision of scientifically arranged accommodation for handling traffic with the least effort and greatest speed and efficiency plays a most important part.

(1) This question runs as follows : « Shunting and marshalling yards for goods trains. Lay-out and organisation ».

CHAPTER I.

General principles of lay-out.

British Railway Practice.

In Great Britain marshalling yard construction has been in a constant state of development, traffic continually outstripping the capacity of the accommodation for it. It is probable, therefore, in this country that changes in designs and organisation are most apparent and where advantages of modern, compared with the older methods are most readily ascertained and judged.

To briefly describe the types of marshalling yard commonly found on British Railways (the principal of which are referred to later), there are, as yet, few constructed on gravitation principles, this being a modern practice, and chiefly applied where new yards have been constructed. Numerous small yards scattered over the lines of the various British Railway Companies are worked on what is known as the « flat shunting » system-many of them, constructed when the railways were first made, have been enlarged from time to time and where enlargement limit has been reached, other yards have arisen to serve as auxiliary to them, often in close proximity.

The effect of this is that several marshalling yards near each other frequently exist to deal with traffic which might advantageously be handled in one.

As regards position in relation to running lines, no fixed practice has been followed, up and down yards respectively being sometimes on each side of the running lines, and sometimes on one side governed by the contour, access, and availability of land at the site; it is, however, usual for the yards to be parallel with the running lines.

Approach lines are usually provided for freight trains to be freely brought clear of the running lines in readiness for marshalling without interference with other movements, and shunting spurs exist to enable yard working to proceed without interfering with train movements.

Most of the older yards are laid out on the « dead-end » principle, *i. e.*, wagons are shunted into terminal or « stop block » sidings; — there are some double ended yards with shunting spurs for working at either end. Shunting operations in yards of this sort require to be more carefully conducted to avoid accidents at the converging ends. In some of them the directional flow of traffic admits of a portion of the yard being worked exclusively for up traffic for periods of the 24-hours, and exclusively for down traffic during other periods.

Some yards have no separate accommodation for the reception of trains which then, before being shunted have to occupy one or more sidings also used for marshalling, and if the wagons on such trains have to be separated for more directions than there are sidings, extra manipulation is entailed, to get them in train order. Similarly trains when formed have in cases to occupy for periods up to train despatch time sidings also otherwise used for marshalling for want of separate departure roads. On British Railways, therefore, are found various yard lay-outs dissimilar from those in the Dominions where develop-

ment has proceeded in a different and freer manner, not being hedged round with difficulties existing in the older country in — for example — acquiring suitable land. For these reasons the Dominions have been able to construct marshalling yards modelled on more advanced plans with experience of the past as well as the latest future outlook conditions.

Principles of location and design.

To refer to aspects for consideration when new marshalling yards have to be dealt with, the site selection calls for most careful attention : In some cases large marshalling yards are examples of evolution by adapting additions to what already exists, extra sidings having been put in where available space rendered this easily accomplished; in others working difficulties have been met by additions improvised to meet temporary conditions at small expense. Yard enlargements of this kind sometimes impair working efficiency and impose a permanent operating cost that might with advantage have been reduced by more complete, if more expensive, schemes.

The tendency has been to patch rather than reconstruct and the disadvantages are revealed in working costs; it may often be more advantageous to re-design a yard to enable wagons to be passed through it more quickly than increase its standing capacity, and it is necessary to remember that the working efficiency is more correctly measured by the wagons which can be passed through it in a given time than by the number which can be held. The solution of a traffic problem is sometimes found in the provision of more but shorter sidings rather than in increasing the total capacity of a yard.

In new constructions it is advisable to anticipate expansion of traffic and future extensions, and this applies to the older and newer countries alike; new yards should be arranged to meet immediate needs on plans which will enable them to be added to at any time in the most effective manner and it is important when new freight marshalling accommodation is contemplated for a careful study to be made of the traffic conditions, as they exist, and are likely to develop, with the best anticipation of change in volume, and character.

The fullest and most comprehensive data available is necessary when considering the provision of new yards, and it is a good practice to appoint a Committee of investigation comprising officers of the Operating, Engineering and Locomotive Departments; who should collect and collate information upon which decisions can be made to obtain the best results.

As to the best lay-out and organisation of marshalling yards it is assumed that the principle of placing them at the most suitable concentration points which will fit in with the stages in which traffic will be handled is generally accepted, and where future development favors, the « hump » method of marshalling will probably be that adopted.

In large industrial districts such as coal-fields, iron and steel producing areas, the volume of traffic to be dealt with assists in making concentration easy. Similar conditions exist in large city districts. Marshalling yards are, however, also frequently necessary at common points where trunk routes converge, and examples may be found in the proposed new yards at Lahore on the North Western Railway of India, figure 1, a junction point for traffic from

six directions, and at Enfield Yard on the New South Wales Government Railways, close to the port of Sydney where the traffic from North and South converges.

Yard site in relation to yard working.

Yards should be laid out to enable wagons to move only in one direction wherever this can be done. Reverse movements cause extra mileage, extra engine hours, greater wear and tear, and interference with yard movements, and it is often well worth expending a larger initial outlay to achieve this forward-only movement of wagons to reduce operating costs.

The relation of the yard to the main running tracks is important; ideally the best position is in the centre of two main running tracks although generally other conditions prevent this. This arrangement has the defect that future expansion is more limited. In the case of the proposed new Harbanspura Lahore Yard of the North Western Railway of India (fig. 1), this lay-out has been adopted and the advantage of such a design is the direct access without interfering with trains entering and leaving in the opposite direction.

The next best position is to have both up and down yard on the same side of the line. In Great Britain an illustration of this practice is the Southern Company's new yard at Feltham, probably the most up to date in this country (fig. 2).

While this arrangement is open to the objection of compelling freight trains to cross a running line for trains travelling in an opposite direction, there are compensating advantages : transfer from one yard to the other can be more freely performed; shunting necessitating another engine when yards are on two sides can sometimes be performed by one where both are together : supervision can be more easily exercised and staff economies effected; the use of sidings can be changed with variations in the flow of traffic and engines of incoming trains can more quickly reach the point from where outgoing trains start.

The up and down yards should be so arranged as to render it practicable to concentrate at a central point of the yard engine sheds and attendant facilities, where they may be most easily reached which applies also to the concentration of the staff employed as well as to tranship sheds, repair sidings and cattle pens.

Yard approach and departure lines deserve careful study in considering lay-outs to avoid the necessity of undue running line occupation whilst at the departure end it is well to have a length of line sufficient to enable a train to be drawn out of the sidings clear of the shunting where a running line path has to be waited for.

CHAPTER II.

Details of lay-out and yard operations.

The ideal lay-out.

The ideal lay-out of a marshalling yard it is therefore suggested consists of three principal factors, *viz.* :

1° Reception lines upon which freight trains may be received whilst waiting to be shunted;

2° Sorting sidings into which wagons

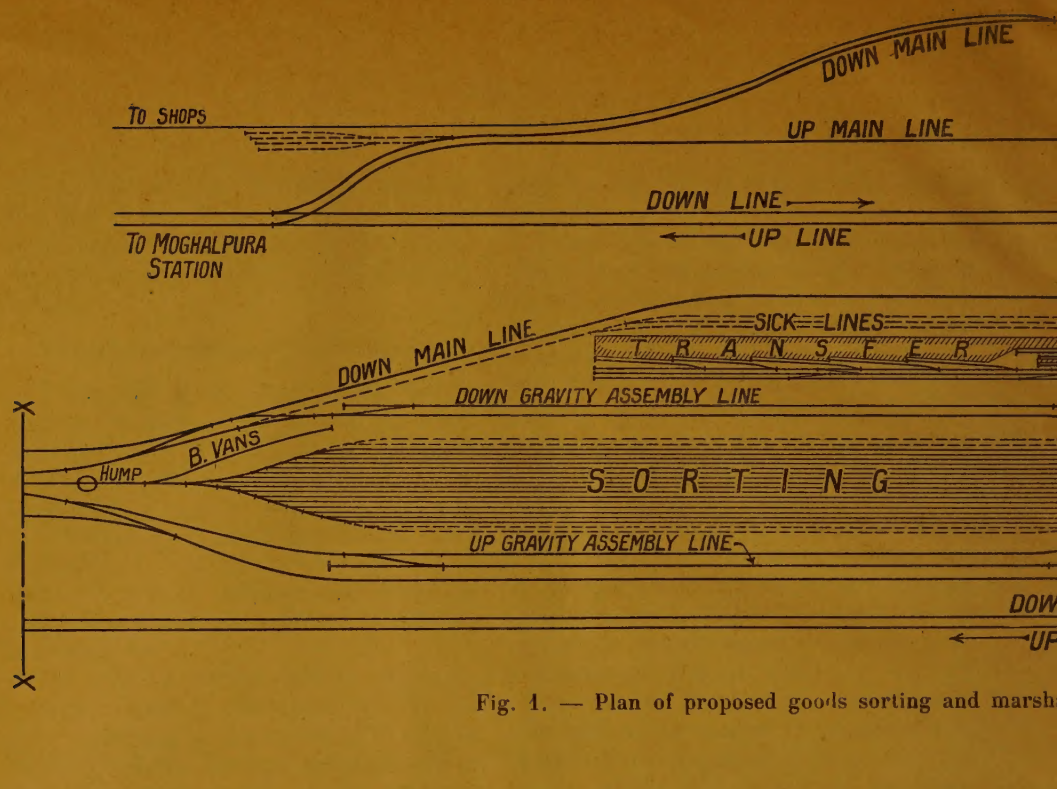


Fig. 1. — Plan of proposed goods sorting and marsh

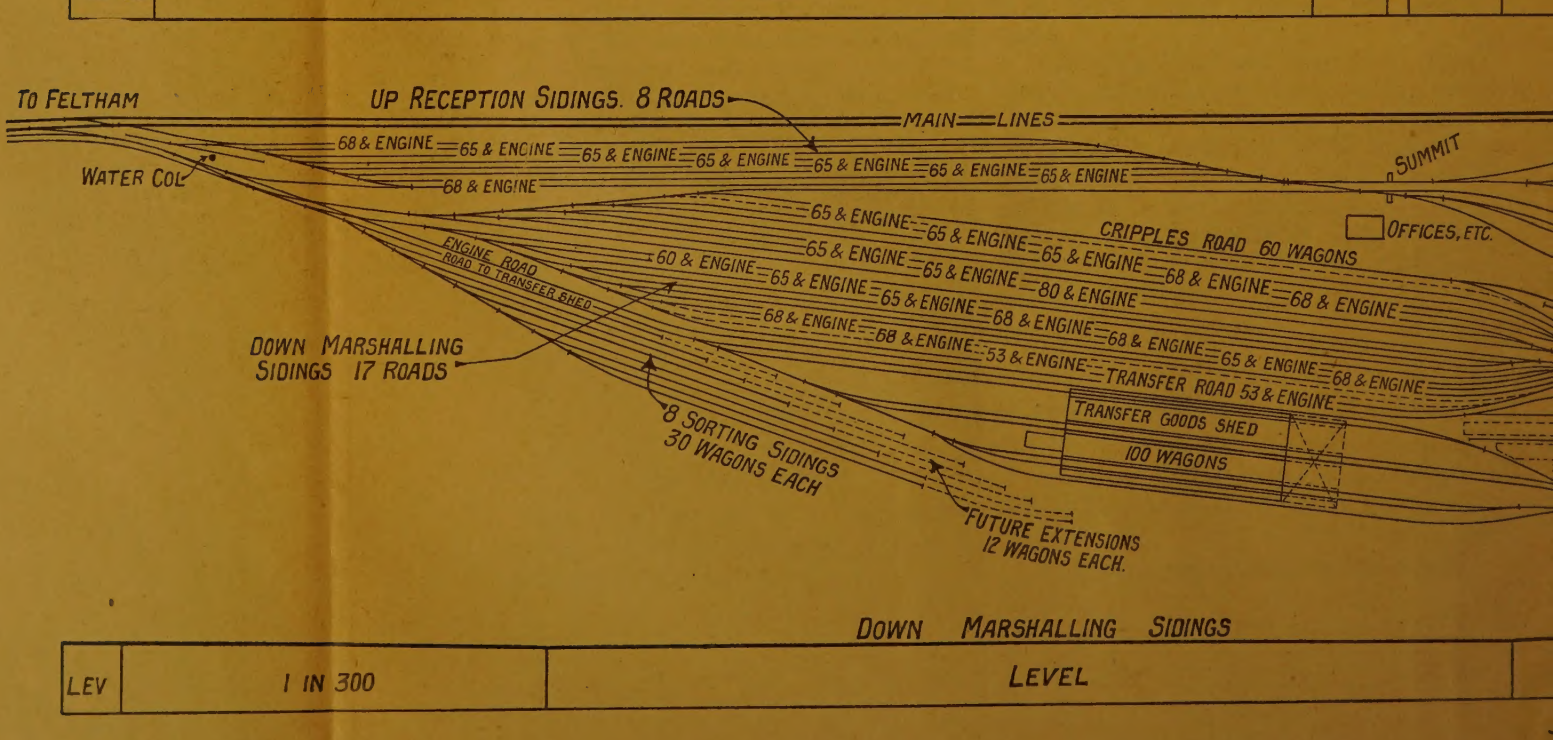
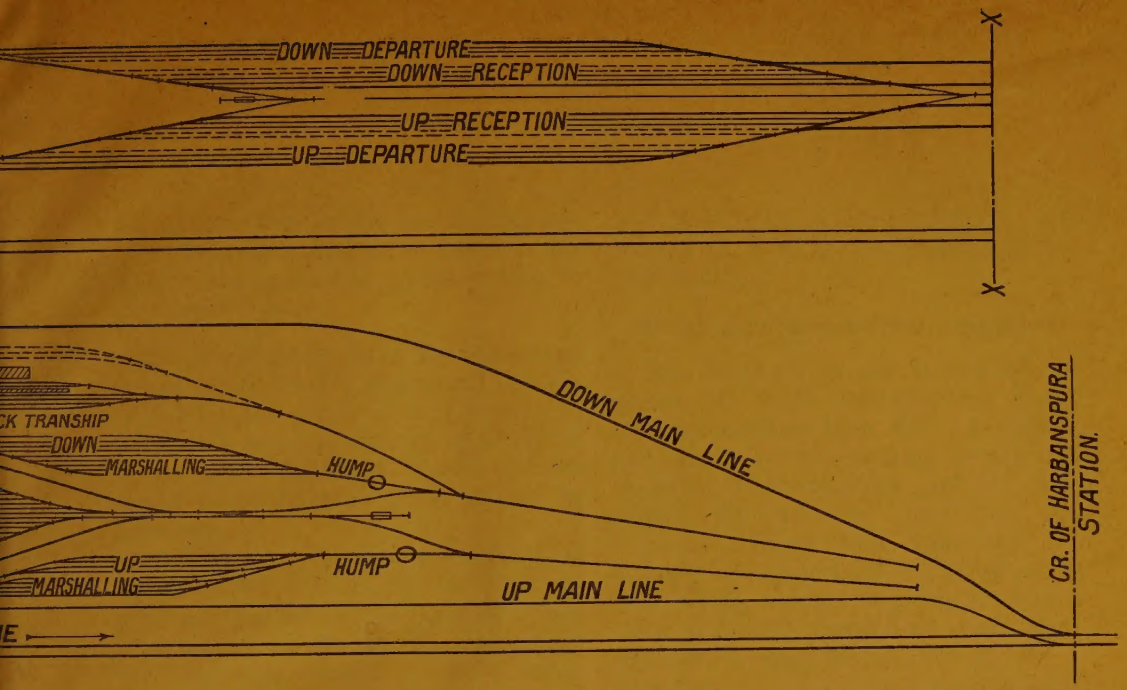
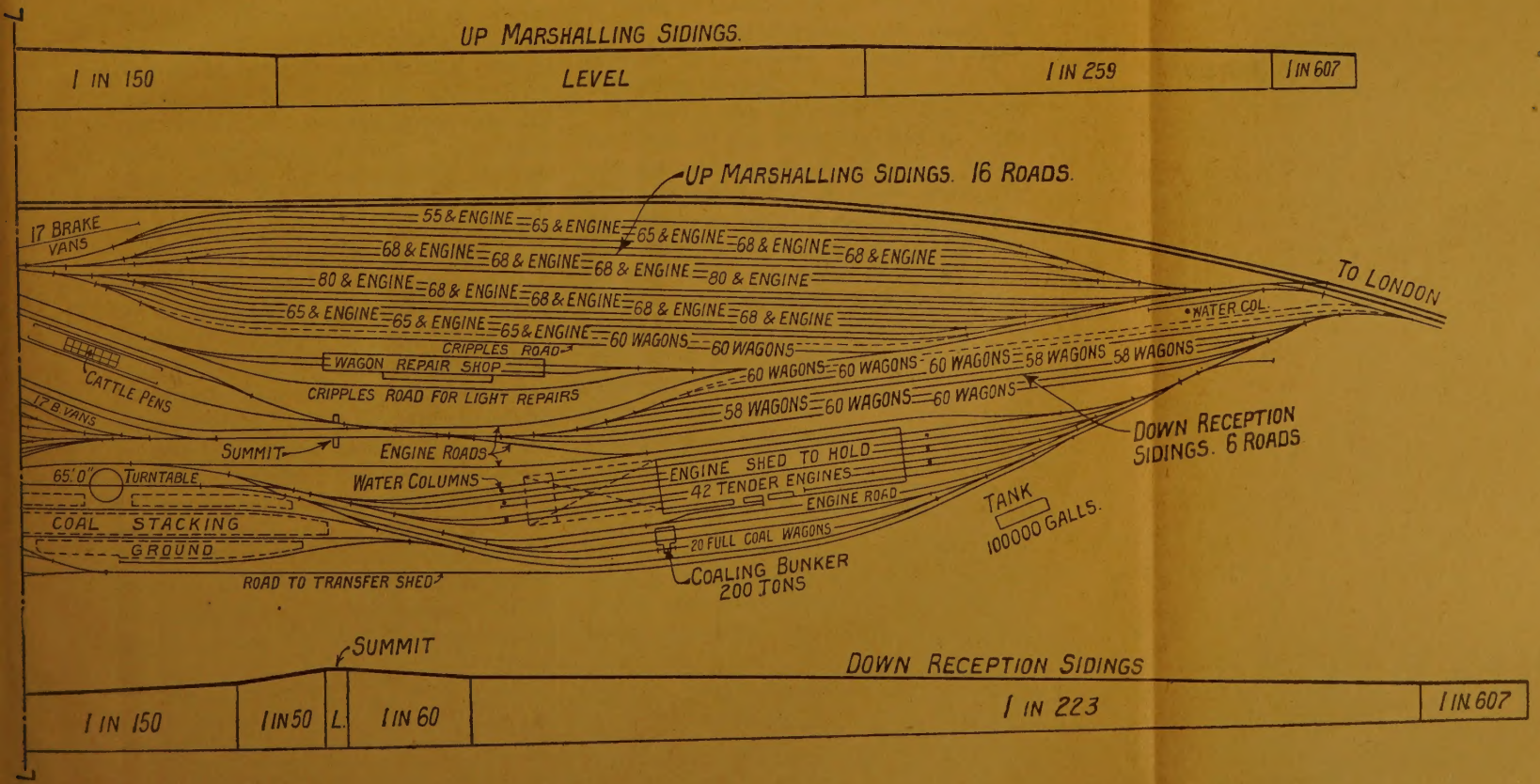


Fig. 2. — Plan of Feltham concentration yard, So



ard, Harbanspura, Lahore, North Western Railway of India.



Railway (London & South Western Section), Great Britain.

for various destinations may be shunted;

3° Departure lines on to which trains when made up may be placed waiting to be worked away.

As to reception lines the governing factor for fixing the length and number of these is the length of the trains to be dealt with and the quantity of traffic to be handled. Sufficient lines to enable trains to be accepted freely should be provided.

At Feltham (Southern Railway of Great Britain) (fig. 2) for example, provision has been made for eight reception sidings on the up side and six on the down side, capable of taking trains varying in length from 58 to 68 wagons, which represents about 50 % of the accommodation provided in the marshalling sidings. At the Toton Yard (up side) of the London Midland & Scottish Railway of Great Britain (fig. 3), 10 reception roads capable of taking trains of 60 wagons serve 28 marshalling sidings, representing 35 % of the marshalling accommodation. On the down side different conditions prevail, 2 reception roads serving 34 marshalling sidings, or 6 %.

At Wath (London & North Eastern Railway of Great Britain) (fig. 4) which deals with a similar class of traffic to Toton, *viz.*, coal, for east-bound traffic 7 reception sidings capable of taking 75 or 80-wagon trains serve 31 marshalling sidings, and for west-bound traffic 8 reception sidings capable of taking 80-wagon trains serve 30 marshalling sidings, representing about 25 % reception accommodation to marshalling sidings.

At Newport (London & North Eastern Railway of Great Britain) 9 reception roads capable of taking trains of 40-60 wagons serve 25 marshalling sidings and the reception accommodation represents 27 % of the marshalling accommodation.

British and Dominion practice compared.

The Railways in the Dominions, by reason of their comparatively recent development have been able to benefit by the results of the working revealed in yards of other countries and it is only within the last few years that new « hump » yards have been laid out. Usually the proportion of reception to marshalling sidings is somewhat higher than in British practice the ratio being about 60 % reception to sorting.

A feature of the yard at Enfield (New South Wales Railway) (fig. 5) is that equal accommodation is provided in all the three different groups of sidings, and it is proposed in the new yard to be built at Tondiarpet on the Madras & South Mahratta Railway of India to provide 10 reception sidings to serve 13 sorting sidings.

While in the majority of the yards the inlet to the reception sidings runs straight off the main line, the desirability of providing a goods loop line running for some distance before the yard entrance is reached, has been realised and where the main line traffic is dense goods loop lines for up and down traffic have been provided. The heavy occupation of the main lines on British Railways has forced the provision of these but colonial traffic conditions do not appear to call for them similarly.

Formation of reception, sorting and departure sidings.

The usual formation of reception sidings is in the shape of a grid (fig. 6) which admits of sidings of equal length being provided, the lines converging

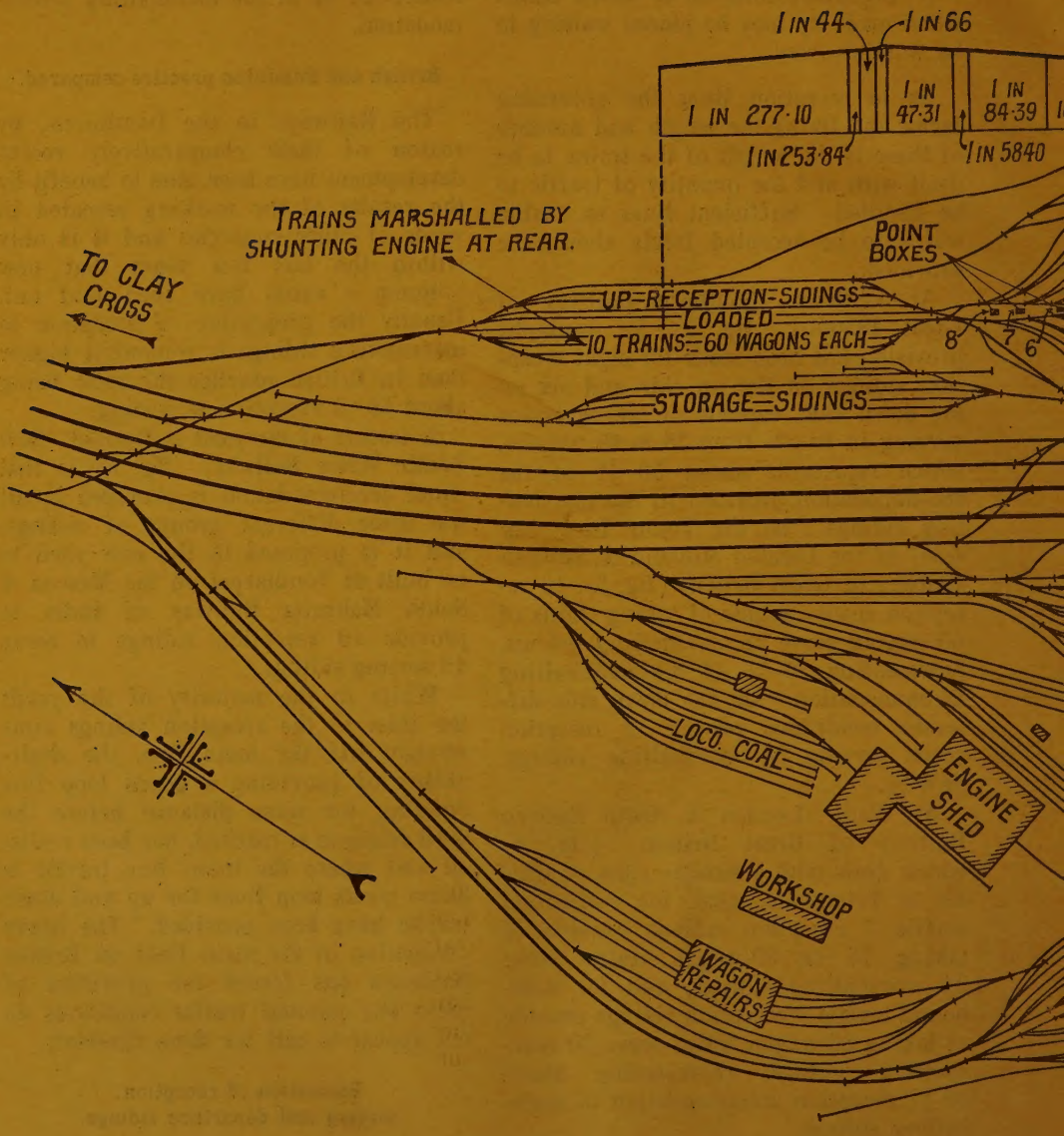
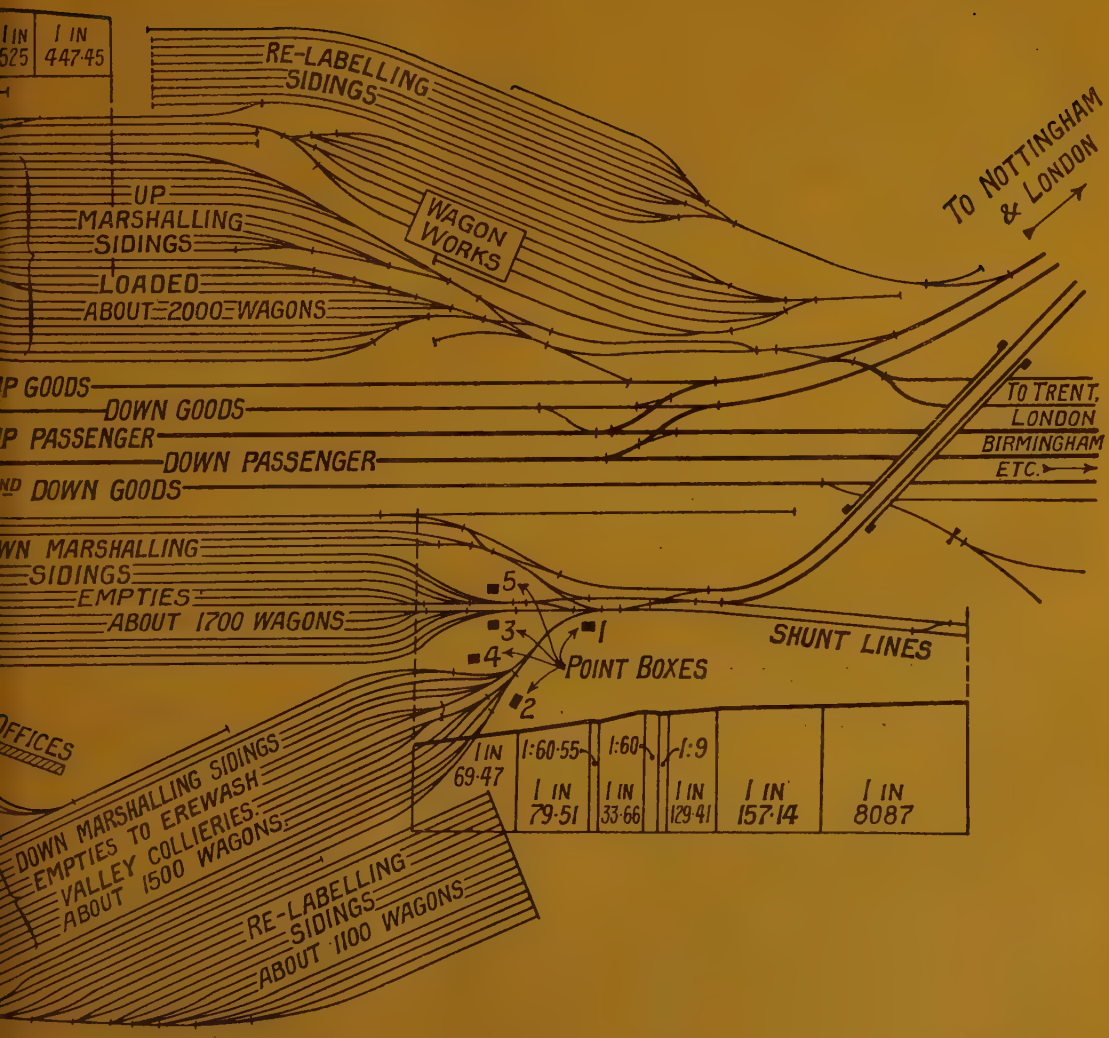


Fig. 3. — Diagram of Toton sidings, I



idland & Scottish Railway, Great Britain.

into one road leading to the « hump » summit at the foot of which an escape road for engines should lead off.

For the sorting sidings, the fan or balloon formation (fig. 7) is that generally favoured, access from the reception lines being afforded by a single road laid over the « hump ». The length of the sorting sidings is also based to some extent on the maximum length of trains dealt with.

In Great Britain marshalling sidings capable of taking from 60 to 80 wagons are long enough and 60 is a favoured maximum.

In the Dominions somewhat longer sidings seem to be favoured and lines capable of taking goods trains of 2 000 feet are in existence and proposed.

Divergent opinion exists on this point, some Railways consider it more expeditious to pull a string of wagons off two roads than to manipulate the whole of the wagons on one road.

Where longer roads are provided it sometimes necessitates, according to the gradient and type of traffic to be dealt with, the employment of more men to control wagon speeds owing so the distances to be covered.

Lines are allocated to districts and in some cases to specified traffics. The marshalling sidings at the exit end should converge into one or more roads for starting trains direct to the main line or passing them to departure sidings : the number of districts or destinations for which traffic has to be sorted is the basis of determining the number of marshalling sidings.

Where separate departure lines are provided they usually correspond with the reception lines and similar principles as to size and length apply. There is some diversity of opinion as to the necessity for separate departure sidings, especially where reasonably frequent margins are available for freight trains to be worked away. Separate departure lines add to maintenance costs, and on British Railways greatly, increase the capital cost owing to the larger area of land necessary, but it is interesting to note in the cases of the Enfield Yard of the New South Wales Government Railway (fig. 5) and the proposed new Lahore Yard of the North Western Railway of India (fig. 1), separate departure lines are provided, or proposed, and their capacity is approximately the same as that of the reception lines.

In some cases where trains have to be despatched in station order, or other special formation, separate sidings for sorting are provided, *e. g.*, on the down side at Feltham (fig. 2) where wagons are first sorted in district sections and then in another group of sidings in station order.

Where possible traffic should be picked up unmarshalled and taken to the furthest point for which all traffic is common the shunting and marshalling being done there for points beyond.

It is desirable that the sorting sidings should be sufficient to enable wagons to be picked up from one or two roads and despatched direct therefrom.

Disposal of train engines and brake vans; cripple sidings, etc.

Facilities should be provided for the quick release of train engines, and should include short sidings on which brake vans can stand, separate sidings for cripple wagons, cattle pens, and in certain cases for wagons which have to be stored waiting orders.

With locomotive running arrangements devolving to a greater extent upon operating officers, and with running costs so high, the importance of avoiding waste

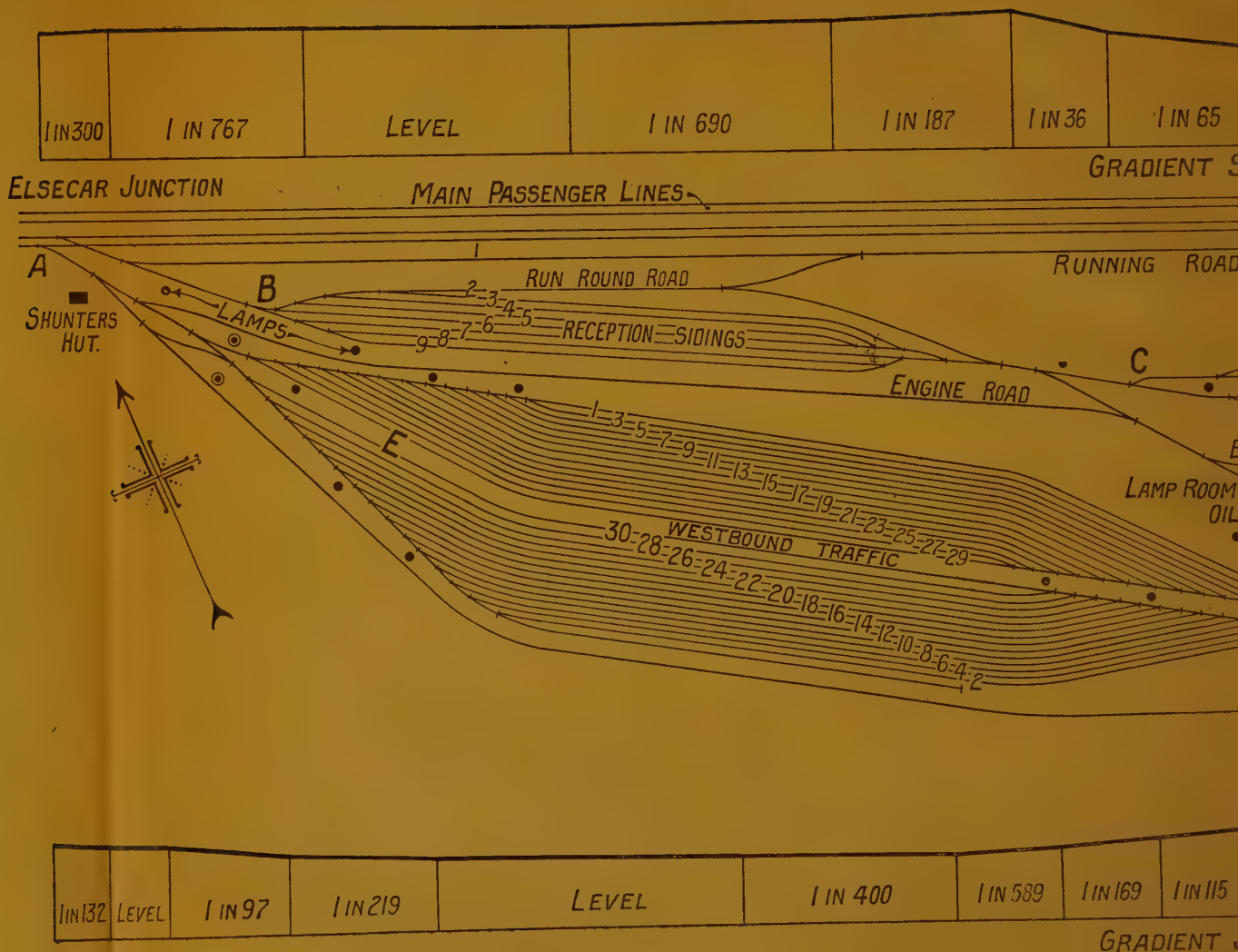
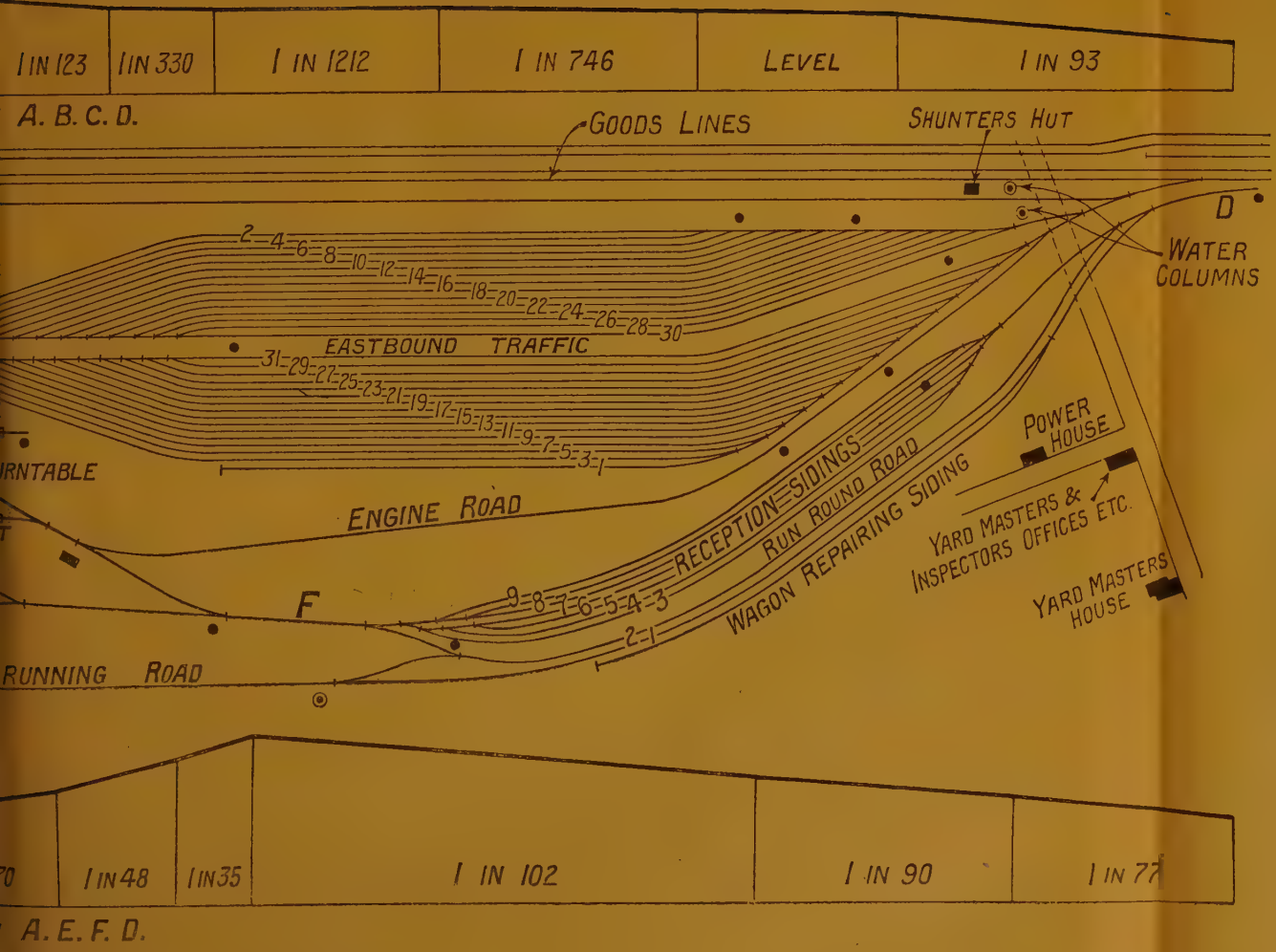


Fig. 4. — Diagram of concentration sidings,



don & North Eastern Railway, Great Britain.

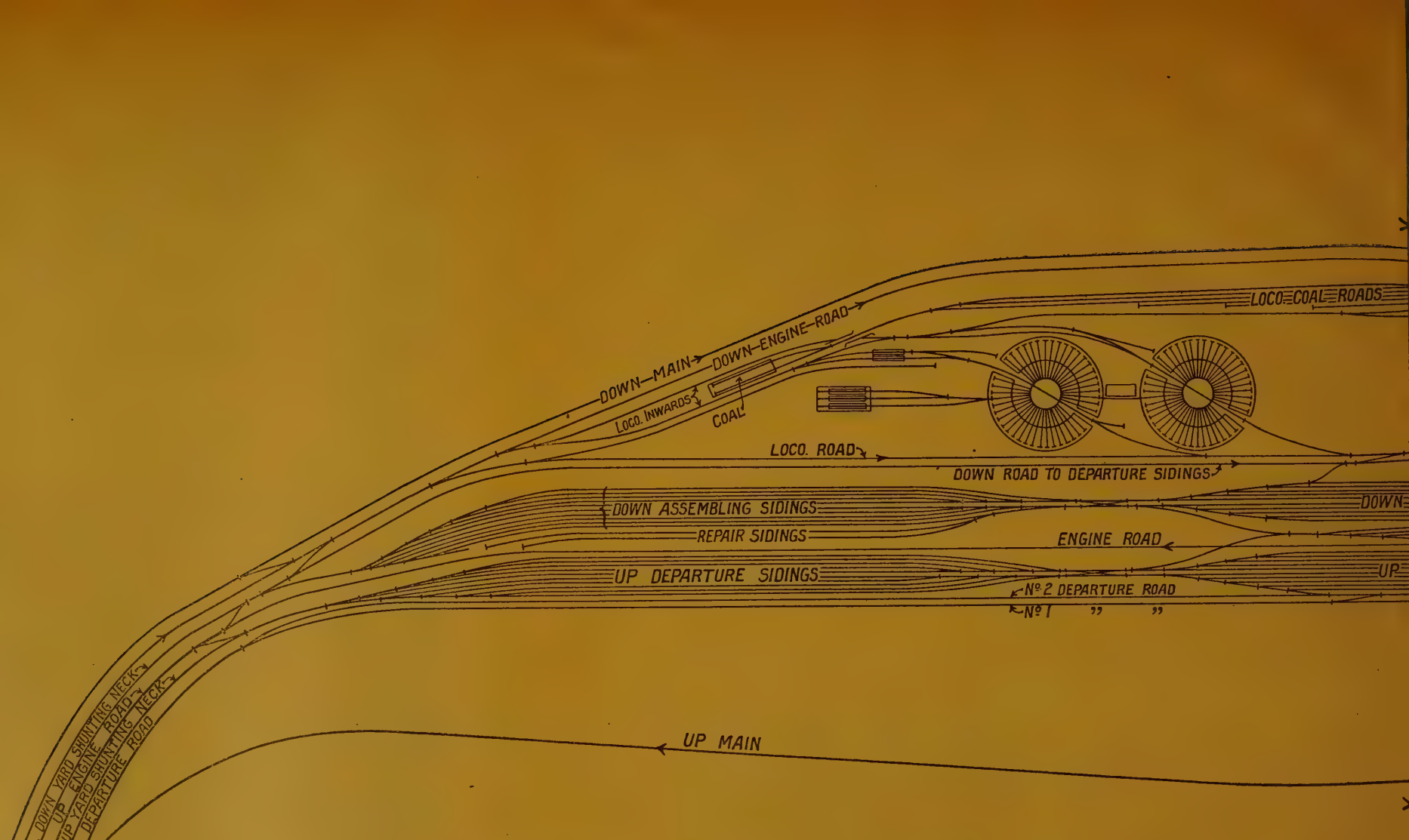
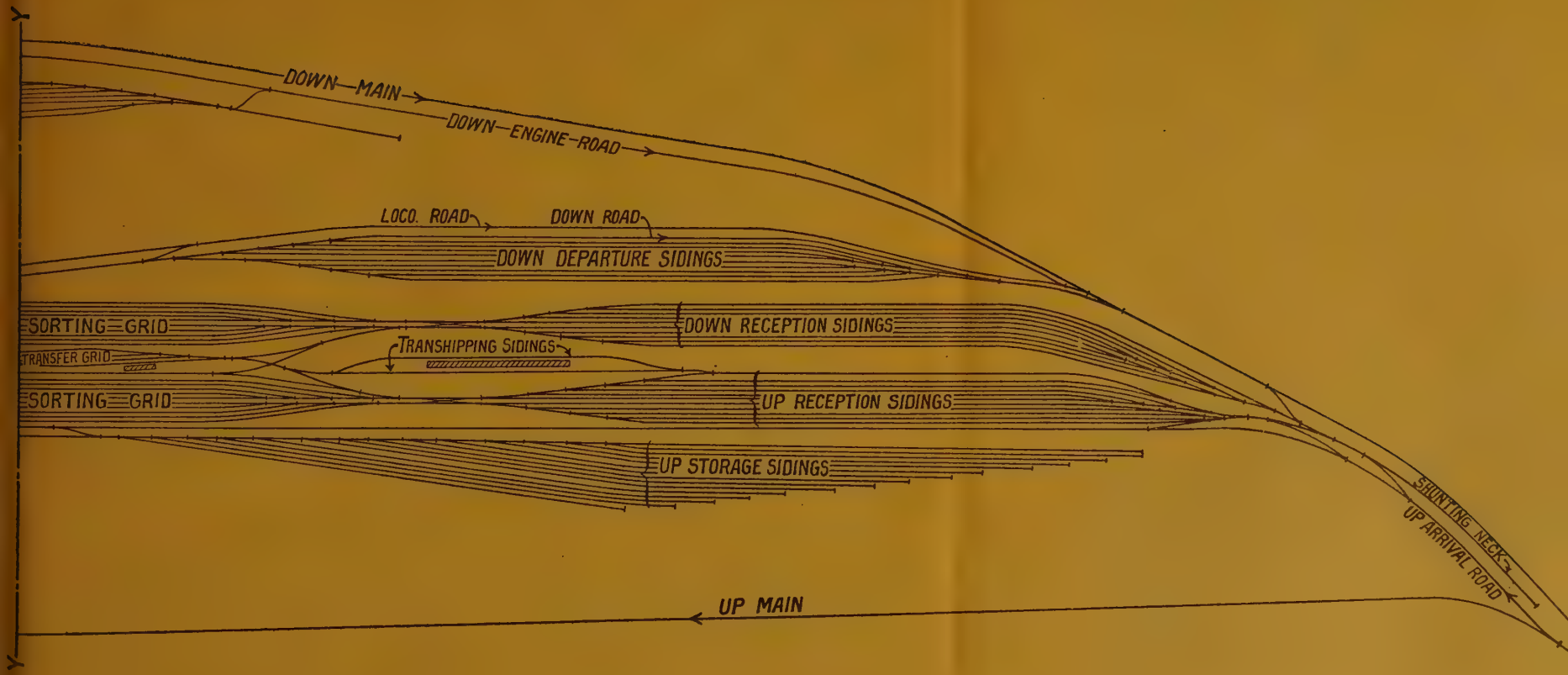


Fig. 5. — Plan of marshalling s



Enfield, New South Wales Railways

time with engines is receiving increased attention.

Escape roads for engines should be provided to admit of the release of train engines immediately a train has arrived on the reception line, and train engines should be able to proceed freely to and from shed or to work a return train without interference with the yard work.

The locomotive shed should be placed near the marshalling sidings it has to serve, and where practicable it, and its attendant facilities, should be within the confines of the yard in a central position in order to secure a minimum engine mileage between train and shed.

Similarly wagon repairing shops, cattle pens, coal stacking grounds, goods transfer

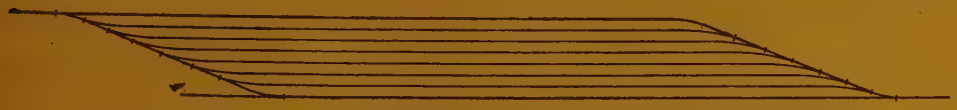


Fig. 6. — Diagram of grid type of reception or departure sidings.

Fig. 7. — Diagram of balloon type of sorting sidings.

shed, and also yard staff and office accommodation should be suitably concentrated in the marshalling yard, so that facilities common to the yard are centralised.

Engine watering facilities should also be placed in such positions as enable engines to take water whilst receiving other attention and without interfering with the yard working. Some companies have provided water troughs at which trains can replenish their supplies whilst running which minimizes the need of engines taking water in yards.

Gravitation shunting methods.

Three methods of shunting by gravitation are in operation in Great Britain and the Dominions :

1° By continuous gradient from reception lines which are also on falling gradients, where the wagons are uncoupled to gravitate into sorting sidings from which they are despatched or drawn on to departure lines;

2° By combined gravity and engine propulsion, which is employed to push the wagons over an apex or summit (commonly termed a « hump ») from where they gravitate into sorting sidings to then work as in method 1;

3° By combined gravity and engine power as in method 2 with the difference that the forward movement is not continuous, the reception lines having had to be laid alongside the sorting sidings, and the summit or shunting « hump » being placed ahead of both. Wagons to

be sorted are drawn ahead and then pushed back over a summit to gravitate into sorting sidings from where they are drawn forward for despatch. The advantage of methods 1 and 2 is that wagons enter the sorting sidings at one end and leave them at the other, whilst in method 3 they enter and leave the sorting sidings at the same end.

The following yards are examples of each of the three methods and diagrams are given showing their principal features.

GRAVITATION METHOD.	COUNTRY.	RAILWAY.	YARD.	Average number of wagons dealt with each 24 hours.	Date opened.	Figures.
1	Great Britain.	London Midland & Scottish.	Edge Hill.	5 500	1875	13
	New South Wales . .	New South Wales Government.	Enfield.	3 500	1922	5
2	Great Britain.	London Midland & Scottish.	Toton.	8 900	1901	3
	— —	London & North Eastern.	Wath.	5 000	1907	4
	— —	Southern.	Feltham.	3 500	1921	2
	— —	Great Western.	(1) Rogerstone.	(3) 10 000	...	15
	India	North Western.	(2) Lahore.	(3) 2 000	...	1
3	Great Britain.	Great Western.	Llandilo Junction.	700	1921	14
	— —	—	Bristol East Depot.	1 200	1923	11

(1) In course of construction. — (2) Proposed. — (3) Contemplated.

Hump operation.

As to certain general aspects of hump yard lay-outs the height of the « hump » or « summit » and the gradient of the lines leading to and from it varies, but there is a large body of opinion favouring a total fall of about 8 feet from the summit to the middle of the sidings.

It has not been found necessary to have « humps » of varying heights to meet changes in weather conditions either in Great Britain or the Colonies, although in some cases they are repacked for the winter to obtain a faster descent from the summit.

The maximum speed of a wagon after leaving the top of the hump should not exceed 10 to 12 miles per hour which is generally obtained by a fall of 5 feet from a gradient of 1 in 30.

In Great Britain a considerable number of wagons are fitted with grease axle boxes and have to be moved with those fitted with oil axle boxes. Of the 650 000 private owners wagons in use on British Railways the great majority are fitted with grease axle boxes and form a

considerable proportion of most train loads.

The gravity speed of wagons fitted with grease axle boxes is much slower than those fitted with oil boxes, and this is accentuated during frosty weather or when a wind is blowing against the vehicles. From tests made it has been established that if a grease box wagon is pushed over a 5-feet « hump » followed by an oil box wagon the latter will overtake the former between 300 and 400-feet from the bottom of the « hump ».

The weight of wagon contents affects the speed and the more heavily a wagon is loaded the faster it runs.

Lay-out of points and switches.

Switches controlling the entrance to the marshalling sidings should give easy curves, and not be further than about 500-feet from the « hump » summit : the Great Western Company of Great Britain conducted experiments recently and found the best results were obtained by placing the king point 75-feet beyond the « hump » summit and fixing the distance between that point and the extreme clearance point of the yard at 450-feet or 525-feet from the « hump » summit. At the Southern Railway Feltham yard the distance from the summit of the « hump » on the up sidings to the first points is only 65-feet and to the second set of points 160-feet, no points being further away from the hump than 500-feet. On the down side, however, the distance to the first points is 200-feet, to the second 290-feet, and the farthest 680-feet, the reason being that the principal traffic dealt with in the up sidings consists of empty wagons, whilst in the down sidings the majority of wagons are heavily laden.

As to the maximum number of sidings in a marshalling yard which can be efficiently worked; the investigations of the Great Western Company gave the conclusion that within the distance of 525-feet from the « hump » summit to the extreme clearance point, 18 sidings as shown in figures 8 and 9 constituted the maximum which would be worked from one « hump » if 8 chain curves were adhered to. 7 chain curves would enable 22 sidings to be brought within the limiting distances, but the sharp radius of such curves is an objection to such a number. The type of lay-out shown in figure 8 gives many advantages over other types by increasing the length of the roads and decreasing the length of the series of loads over which shunting takes place. It is desirable that sidings inside clearance points should be straight for running and sighting purposes.

For shunters to have sufficient space to operate their shunting poles a minimum space of 8-feet should be allowed between the sidings, and if lamps or posts have to be fixed between the sidings the spacing should be increased to 12-feet.

With « hump » shunting trains comprising 60 to 70 wagons, requiring 50 to 60 cuts, can be sorted within 15 minutes, as compared with 45 minutes under flat shunting.

With reasonable care there is no greater risk of damage to wagons or their contents in « hump » shunting. As to the limitation of the number of wagons which can be passed over the hump in one cut there is a difference of opinion but a strong feeling exists that cuts should not exceed six wagons. It is found desirable to pass wagons containing loads of exceptional dimensions, brittle goods, or defective wagons over the hump with the engine attached, and a man accompanies a brake van to attend to the brake. If live stock is passed over the hump an engine is attached but some companies avoid live

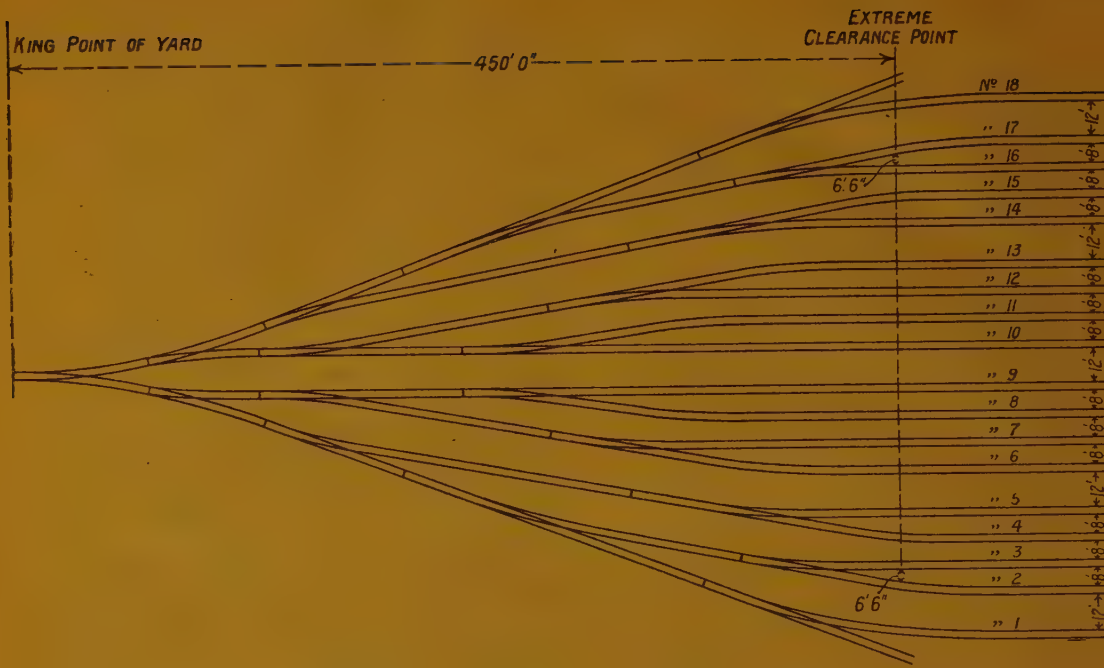


Fig. 8. — Diagram showing lay-out of leads.

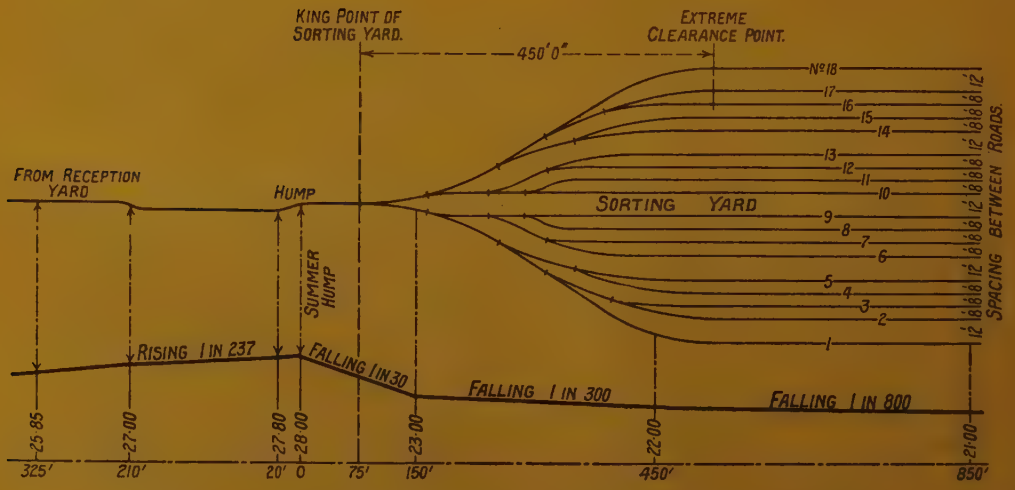


Fig. 9. — Diagram showing lay-out of hump and leads therefrom.

stock being worked over a hump owing to the sharp change in gradient.

As to regulating the speed of wagons proceeding from the hump into the sorting sidings men are placed near the points leading to the various sidings to follow up the wagons and apply brakes to prevent undue impact with other wagons. These men are variously named wagon chasers, brakesmen, or shunters, and are generally allocated in the ratio of one to about three or four roads.

Wagons fitted with the standard either side brake, can be checked or stopped whilst travelling at speeds at which it would not be safe to attempt to apply the ratchet brake.

A very effective means of bringing wagons to a stand is the shoe type of portable shunting skid which placed on the rail in advance of an approaching wagon brings it to a state of rest in about its own length the backward movement of the wagon after its running has been arrested throwing it clear of the shoe and enabling it to be removed.

In « humping » wagons a regular speed of about two miles per hour is found to be the most satisfactory.

Typical instructions drawn up by the Great Western Company of Great Britain for working hump yards are given at the end of this paper.

Shunting power.

On some railways shunting engines of a special type have been constructed capable of maintaining a consistently slow rate of speed. On the Southern Railway of Great Britain a special class of engine of the 4-8-0 tank type is used with driving wheels of 5 ft. 1 in. diameter, boiler pressure of 180 lb., tractive effort 34 000 lb. These have been found very efficient.

Other British Companies have also constructed engines specially designed for humping work.

Switch operation.

The control of the whole of the switches leading to the sorting sidings should be centralized in one cabin placed near the hump. This enables all switching movements to be controlled by one man and reduces the number of men necessary in the sorting sidings.

At a number of yards the points are operated by power with good results, electric, pneumatic, or electro-pneumatic installations being generally favoured, *e.g.*, at the Southern Company of Great Britain's Feltham Yard (fig. 2) the points are electrically worked and centralised in one box for each set of marshalling sidings. The hump signal cabins each contain a diagrammatic operating board (fig. 10), instead of a series of levers. Upon a sloping table all tracks concerned are clearly shown, with one or more small indicating lights at the various points and with two press buttons adjacent to each, coloured respectively red and white in each pair. All the points are electrically operated and move almost instantaneously as one or other of the buttons is pressed according to the direction required. A small white light remains illuminated as long as the corresponding points are fully over one way or the other. As the points change it is extinguished, but as soon as the tongue is fully home it becomes illuminated once more. The other light indications are red and green to show the occupancy or not of the entrance portion of each siding, red showing as a shunt runs down over the track circuited portion, being replaced by a green light when the wagon or wagons is or are clear of the track circuit and therefore well down in the siding.

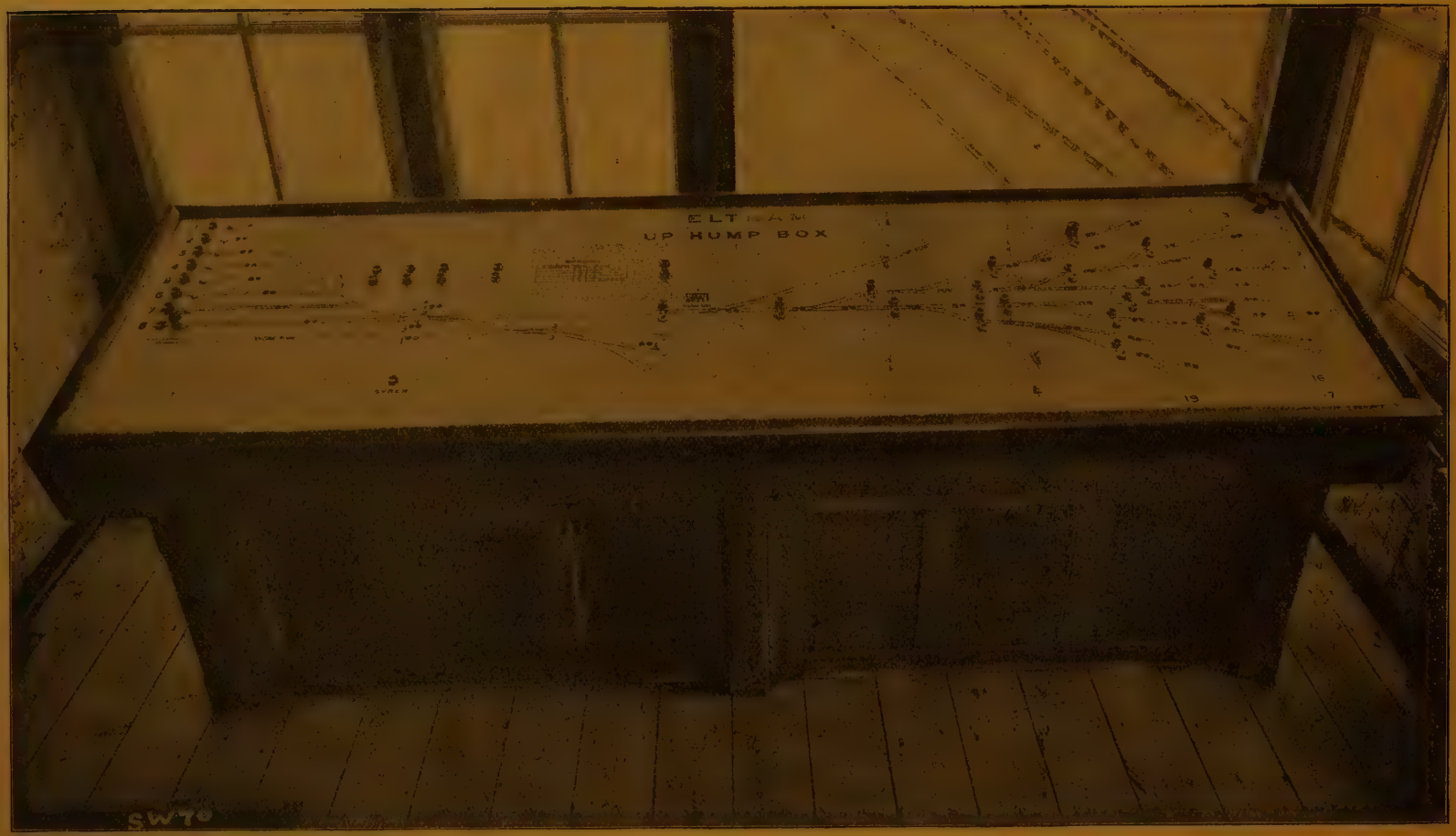


Fig. 10. — Diagrammatic operating board, signal cabin, Feltham yard, Southern Railway of Great Britain.

Regarding the methods adopted for indicating the siding into which wagons have to be shunted, the number of sidings is usually chalked on the front of the wagon but at Bristol East Depot an electrical indicator, figure 12, operated by plug at the hump summit shows in the lever cabin which line is required. Shunting work in hump yards can be performed as expeditiously at night as during the day with good lighting which is of course important and electric lighting by large arc lamps gives excellent results, although good results can be obtained from gas or vapourised petroleum.

When installing lighting it is desirable to place the lamps in such positions as will prevent casting shadows because sharp contrasts of light and darkness are disturbing to shunters who are better able to work in complete darkness than where alternations from bright lighting to darkness take place.

At some places the nature and volume of traffic does not justify hump shunting, and in such cases it has been found of assistance to the shunting operations to construct the sidings on a gradient of about 1 in 400 falling towards the stop blocks, which enables more cuts to be made in one shunt without reversing the engine.

CHAPTER III.

Yard and staff organisation.

Disposal of yard buildings.

Depot Masters' Offices, Mess Rooms, and where provided, sleeping quarters for trainmen, also wagon repairers' buildings should be placed in the most central positions as if they are scattered, supervision cannot be exercised so effectively.

Hostels for trainmen should be placed where men can be quickly called but where the men taking rest can be reasonably quiet. In Great Britain experiments in the provision of hostels have been tried with varying success; usually the men prefer to obtain lodgings off the railway premises, but in the Colonies where the country is more sparsely populated and accommodation more difficult to obtain, they should prove successful.

Although such details as type of rails, chairs, ballasting, etc., used in marshalling yards come within the scope of the Engineering Department, it may be noted that in England the standard 90 lb. bullhead rail is generally adopted and standard transverse chaired sleepers, but in India metal sleepers are employed owing to the ravages of insects causing timber sleepers to be eaten away.

For ballasting, in England and New South Wales ashes and gravel are generally used, but sand and stone are employed in India.

In most yards modern types of urinals, W. Cs., or latrines are provided.

Control of yard movements.

Beyond the signals between the running lines and the marshalling yard there is little signalling by means of fixed signals. A fixed signal controlling the hump is provided, which when placed in the all-right position indicates to the drivers of the hump shunting engine that the humping of a train can be carried on, and must be stopped upon being reversed.

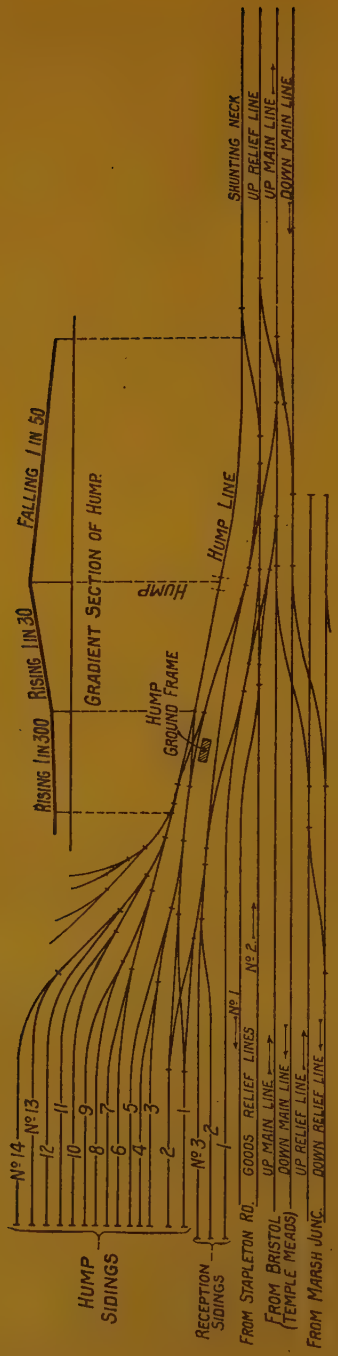


Fig. 11. — Diagram of « hump » yard, Bristol (East Depot) Great Western Railway of Great Britain.

In addition to this signal it has been found advantageous to instal a « Klaxon » horn, which can be operated by the shunter in charge of the hump to indicate any requirement quickly to the hump engine driver, and by a series of short or long blasts drivers are informed to quicken or slow down shunting movements.

In the signal cabin controlling the points leading from the hump to the sorting sidings in some of the yards an electrically operated diagram board has been installed (fig. 11). This shows by means of coloured lights whether moving wagons have cleared points leading to roads upon which they are intended to run.

A necessary adjunct to a marshalling yard is good telephone facilities, and in some of the modern yards this is provided by a switchboard fixed in the Yard Master's Office connected with all the important places in the Yard and Control Offices.

Where telephone instruments are provided in the yard for the use of shunters, loud sounding bells fixed outside the telephone cabinets afford an efficient means of gaining attention.

Tranship shed.

Although not generally established, there seems to be a movement towards the provision at concentration centres of freight tranship sheds suitable in such yards owing to break in the journey of a wagon and if at the same time an opportunity can be taken of re-loading to make more through and better loaded wagons to destination, transit is expedited.

In England there is considerable scope for the development of this as the transit of small consignments is often longer than that of through truck loads. This has received prominence in the Colonies and in India the transhipment is contract-

ed for and performed by outside labour.

Separate accommodation is usually provided for the repair of cripple wagons, but is frequently found to be inadequate and they often get mixed up with other wagons.

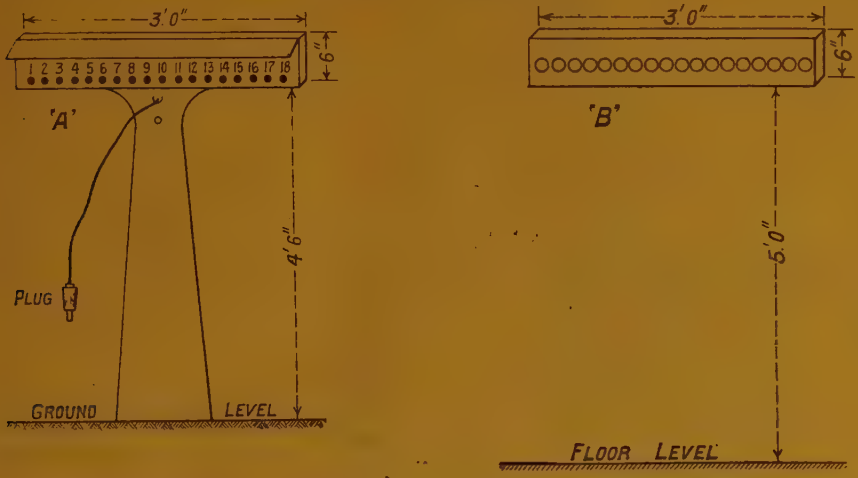


Fig. 12. — Diagram showing electrical wagon indicating apparatus, Bristol East Depot, hump yard, Great Western Railway of Great Britain.

Note.

'A' shows plugging board fixed on hump.
'B' shows indicator placed in signal cabin just over point levers.
On plug being inserted in either of holes numbered 1 to 18 diagram 'A', a corresponding illuminated number appears in indicator 'B'.

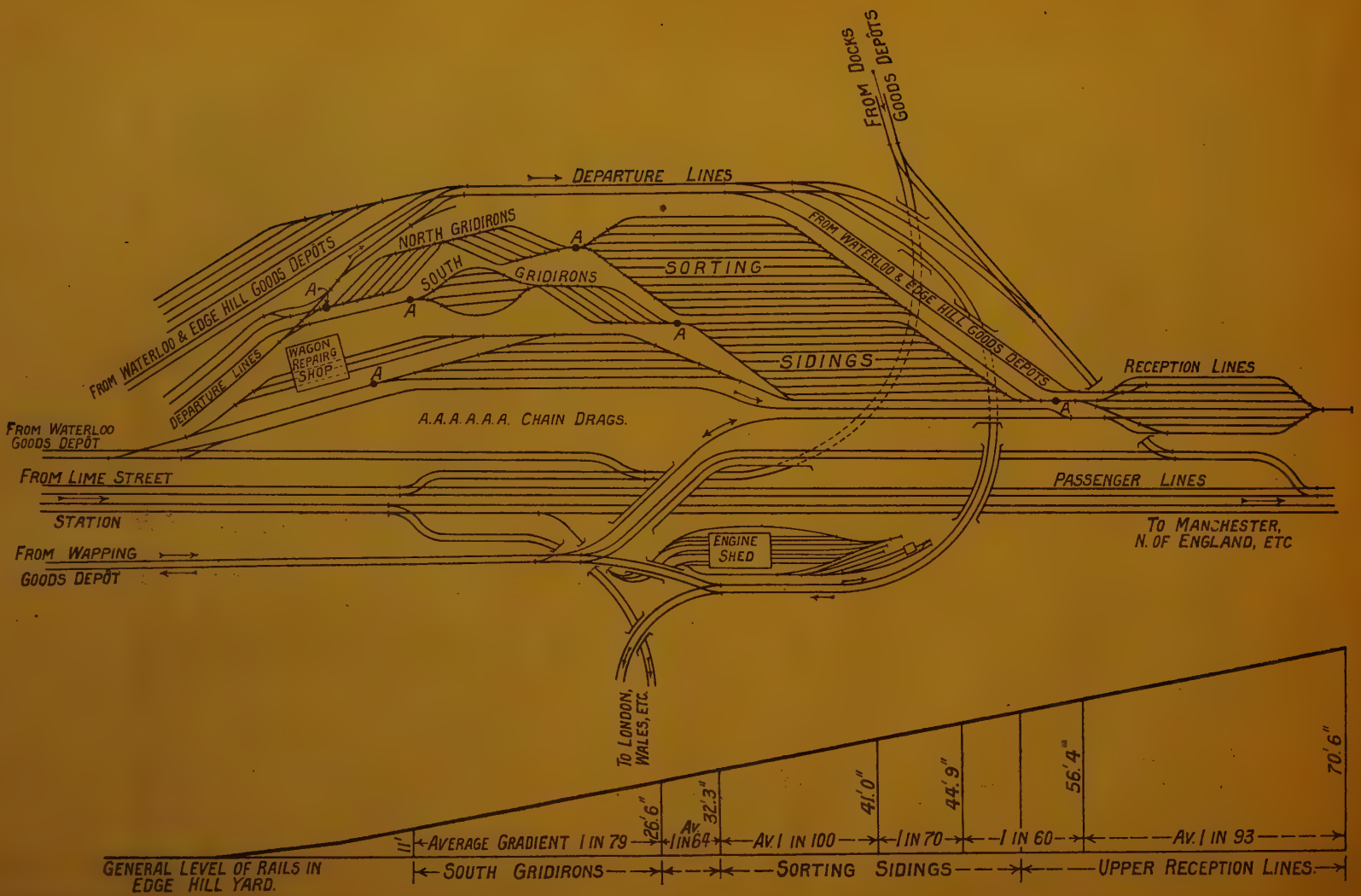
The difficulty in England is more acute owing to the large number of private owners' wagons, the repairs to which are carried out by private repairing firms, which results in wagons being out of repair longer than they sometimes need be, causing longer occupation of sidings.

Staff organisation.

Dealing with staff organisation, the selection of a yard master with the necessary qualities of initiative and forethought is most important. As well as being thoroughly conversant with the working requirements he must be able to lead and control staff; he is essentially an out-door man, and his indoor duties should not include numerous details. He should be quickly able to visualise awkward positions and deal with them. He must know how and when to curtail or increase staff and engine power.

Next to the yard master sometimes a deputy or assistant yard master is appointed, and in Great Britain the general practice is to appoint inspectors for each turn of duty, the 24-hours being usually split into three turns of eight hours, and, as in the case of the yard master, initiative has an important bearing on successfully carrying out the work.

Next there is a foreman or head



Longitudinal section of the marshalling and sorting sidings.

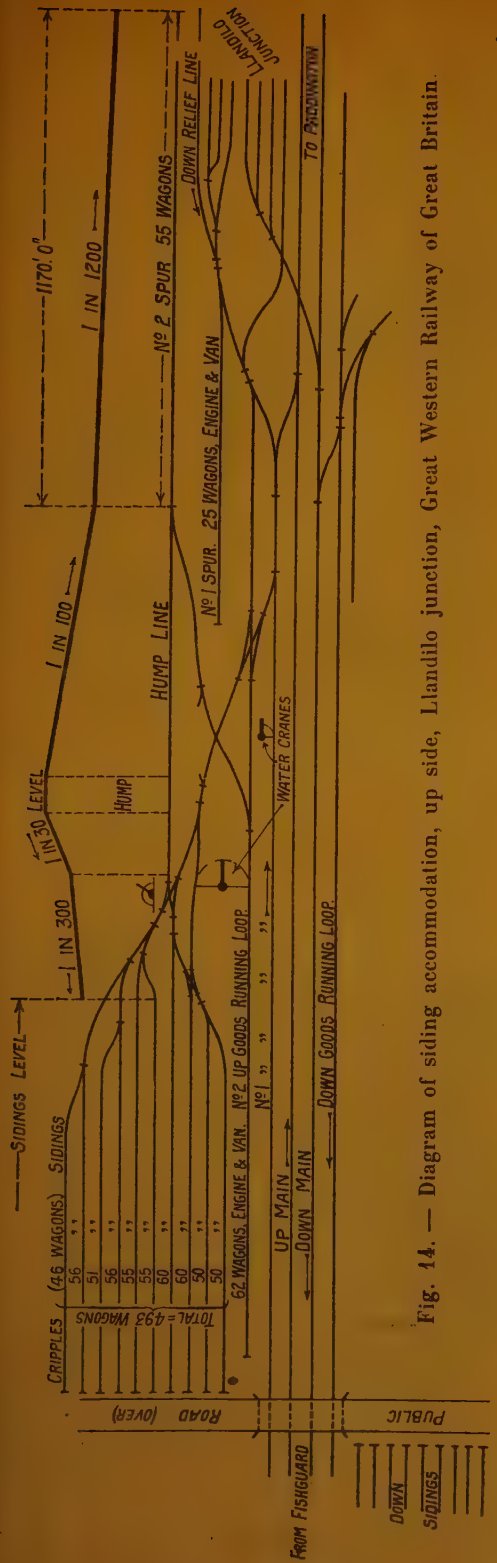


Fig. 14. — Diagram of siding accommodation, up side, Llandilo junction, Great Western Railway of Great Britain.

shunter, assisted by under shunters, also wagon markers, number takers, telephone boys, etc.

In hump yards usually a yard foreman is in charge of the hump, assisted by a head shunter, one man in the cabin controlling the siding points, one chalker and three brakesmen (sometimes termed wagon chasers) for each turn of duty.

In addition, there are usually a head shunter and two assistant shunters for coupling and forming trains for despatch, and number takers, lads where the tonnage loading of trains is in operation, wagon examiners, greasers and repairers.

Coming under the control of the yard master, whilst within the area of his jurisdiction are also goods guards, brakesmen and in some cases enginemen and firemen.

Records of work performed.

As to statistics obtained in respect of yard working, these vary, but in Great Britain information is now prepared in a standard form for the Ministry of Transport showing the number of loaded and empty wagons dealt with in the more important yards of each railway, the number of engines employed, shunting staff, and wages paid. These enable information to be compiled of the number of wagons detached per man hour of shunting staff and per pound sterling of wages paid, and number of wagons detached per total engine hour, per working day, and per train.

It has been found stimulative to publish for the information of the staff particulars of the number of wagons shunted, shunting power used, and wagons damaged, per turn of duty. This has encouraged a competitive spirit and sporting rivalry on the part of the men, and has been productive of good results.

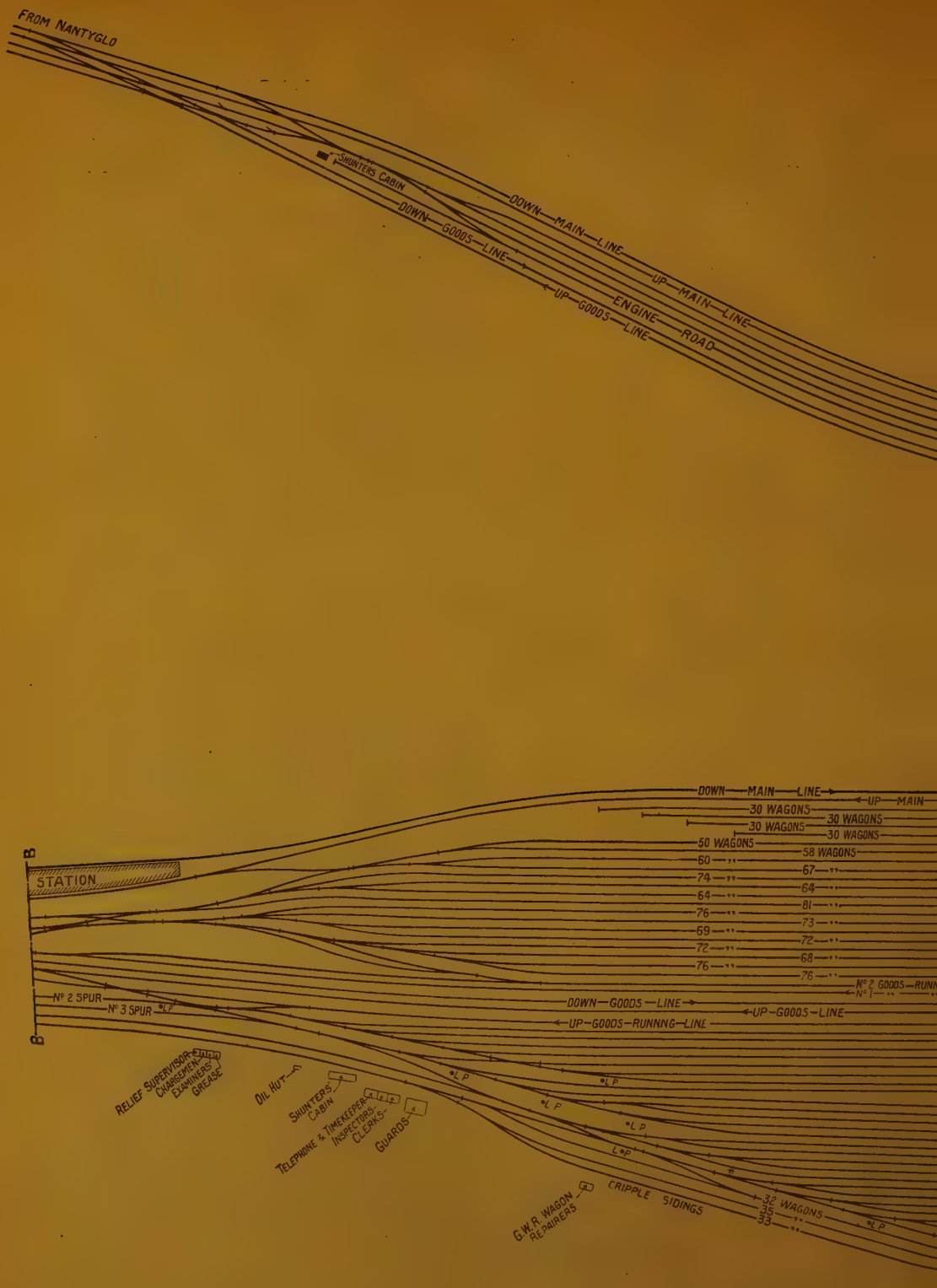


Fig. 15. — Plan of Rogerston

at Western Railway of Great Britain.

CONCLUSIONS.

From the replies received from the various administrations, and from experience, the following conclusions are arrived at :

1. — The lay-out of Marshalling Yards on the « Hump » principle is the most economical and efficient. « Hump » shunting is quicker, less costly, and entails less risk to shunters and less damage to wagons than flat shunting.

2. — When increasing accommodation in existing yards it is well to consider redesign to introduce the « Hump » method of working, and secure the forward only movement of wagons.

3. — A sharp division should be made between marshalling and storage yards, and the lay-out and equipment of the former should have as its chief object the rapid manipulation of wagons.

4. — In designing yards for future requirements the conditions likely to obtain for a considerable period ahead should be regarded, so that if only an instalment is proceeded with future extensions may be carried out on a complete original design, and the character, as well as the volume, of the traffic should be considered.

5. — Close collaboration between the Operating, Locomotive, and Engineering Departments as to collection of data and selection of design should take place when schemes for new yards are being dealt with.

6. — Placing up and down yards on separate sides of the line is not economical and where practicable they should be on the same side of the line. The best access to, and egress from them should be secured.

7. — The ideal lay-out comprises three groups of sidings, *viz.*, reception, sorting, and departure groups.

8. — The locomotive shed should be placed in a central position in the yard. Advantages can also be obtained by the Yard Master's Office, mess rooms, and other structures being placed in a central position in the yard.

9. — Statistics showing working results should be regularly obtained, and be circulated amongst the staff to encourage and stimulate their interest.

APPENDIX.

Great Western Railway of Great Britain : Bristol East Depot Hump Yard.

INSTRUCTIONS FOR WORKING.

1. — On arrival of an up freight train on No. 1 or No. 2 relief line the train engine will be released and the wagons drawn by the shunting engine on to the hump line, where the shunter in charge will mark, — in chalk on the end of each wagon, — the number of the siding into which it is required to be sorted, — the shunting engine will then push the wagons over the « hump » and they will be uncoupled near the summit to gravitate into the respective marshalling sidings.

2. — Great care must be taken in shunting over the « hump » and the speed must be regulated so that the wagons may not be « buffered-up » by the engine after leaving the summit of the « hump »; — the best results will be obtained by maintaining a speed of about two miles per hour when pushing over the « hump ».

3. — Not more than four coupled wagons may be allowed to gravitate over the « hump » at one time (see note A).

4. — Oil-box wagons move more freely than those fitted with grease-boxes, and due regard must be had to this in regulating the speed of oil-box wagons following grease-box wagons down the « hump ».

5. — The signal at the summit of the « hump » will be operated by the shunter in charge, and when wagons are being passed over the « hump » the signal will be placed to the « all-right » position, but must be put to « danger » immediately in any emergency necessitating shunting being stopped, and the driver of the propelling engine must be prepared to stop instantly in such circumstances. After disposal of a batch of wagons the signal must always be placed to « danger ».

6. — The shunter who uncouples the wagons near the summit of the « hump » is responsible for regulating their movements from the top, and the shunters attending to the brakes in the sidings must control the wagons so as to avoid rough shunting where necessary, making use of a shunting skid, a supply of which is provided for the purpose of checking the speed of any wagon moving too fast.

7. — When it is necessary to pass over the « hump » a wagon carrying a load of exceptional dimensions, — girders, or brittle goods, or a specially constructed vehicle, — the shunter uncoupling must test the brake or brakes, and a shunter must accompany the wagon into the sidings and control its movement so as to prevent it from coming into violent contact with wagons already in the siding or the stop-blocks, and shunting over the « hump » must be stopped until such wagon is brought to rest, and care must be exercised in subsequent shunts to avoid collision with or damage to the wagons or loads of exceptional character referred to.

8. — Boiler wagons, and wagons with defective brakes, and wagons of live stock, must not be allowed to gravitate from the « hump », but must remain attached to the engine until they are placed in the sidings and are at a stand.

9. — A brake van must not be gravitated from the « hump » unless there is a man riding in it to attend to the brake.

10. — Telephones are provided between East Depot main line box and the hump yard ground frame. These include the yard circuit and Bristol Control Office. The shunter operating the ground frame is responsible for attending to the telephones.

11. — A Klaxon horn is fixed on the up side of the line about 150 yards on the London side

of East Depot main line signal-box which must be operated by the shunter working the ground frame during humping : operations in accordance with the following code :

« Go ahead »	1 note
« Come back » (to « hump » wagons into siding) . .	2 notes.
« Stop »	3 notes.
« Obstruction-danger » . .	6 notes.

12. — Portable shunting skids are provided in the « hump » sidings to assist the shunters in controlling the movement of wagons. One of these must be used when a wagon is observed to be running from the « hump » at a speed which is likely to cause damage to it or other wagons standing in the siding or their contents. In order to avoid damage to the skids and possible derailment, a skid must not be placed on the rail in such a position that the approaching wagon could push it along a line when there is a crossing or the tongue of points.

The skid must be taken off the rail immediately after the wagon to which it has been applied has been brought to a stand.

13. — If during a slight fog or snowstorm the shunter in the ground frame is unable to read the numbers chalked on the wagons, the inspector in charge must arrange for the numbers to be called out before the wagons leave the level of the « hump » (see note B). During dense fog or falling snow gravitation shunting must be suspended.

Note A. — This instruction has now been modified to permit 5 coupled wagons gravitating over the hump at one time.

Note B. — This instruction has been superseded by the introduction of an electrical indicator enabling the shunter uncoupling wagons on hump to indicate to the signalman the roads on which they are required to run.

[656 .25]

REPORT No. 1

(America)

ON THE QUESTION OF FIXED SIGNALS (SUBJECT IX FOR DISCUSSION AT THE TENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION), (1)

By W. H. ELLIOTT,

SIGNAL ENGINEER, NEW YORK CENTRAL RAILROAD.

Figs. 1 to 27, pp. 910 to 944.

Fixed signals.

In writing on the subject of fixed signals, it is proper to state that the standards and practices described are those of the railroads of Canada and the United States and not of roads of other countries, regarding which, one is not in position to obtain or to give definite information.

The art of signaling, as followed on American railroads, has been largely developed to conform to and be in accord with the practices prescribed by the Standard Code of the American Railway Association. Designs of parts and principles of signal construction have been developed in the main through the work of the Signal Section of the American Railway Association, the official record of which is published as a manual issued by the Association. With this manual covering practically the entire field of signaling, except for recent developments, it will be found the greater part of the drawings herein presented are from the Association's manual.

Semaphore signals of the earliest design were constructed with the arm projecting from the mast towards the track as viewed from an approaching train, to represent as nearly as practicable the position naturally taken by a person desiring to signal a train with an arm or flag. In England the engineman rode on the left side of the engine and the mast was placed on the left side of the track, the signal arm projecting to the right of the mast towards the track. The signals first used in America were imported from England and in consequence were arranged with the arm projecting to the right of the mast. With the engineman occupying the right side of the cab the mast was placed on the right side of track where it could best be observed by the engineman. In so placing the signal without changing the arm, the arm projected away from the track and was not in as good or as distinctive a position as if the arm projected toward the track. One prominent steam road in America is using semaphore arms that project to the left of the mast, as are also a majority of the

(1) This question runs as follows : « Fixed signals. Principles of signalling for lines with dense traffic and for large stations. Form of day and night signals. Signal lights. Automatic block signals. »

trolley lines; this change from the general standard being made necessary because the row of trolley poles along the track obscures the view of the arm if it projects to the right of the mast.

The signals first used in America were of the lower quadrant type, moving to a position 60° below the horizontal to give the « Proceed » indication. The weight of the arm was such that a comparatively heavy spectacle, together with the weight of the operating rod was required to cause the signal to return to horizontal position to display the « Stop » indication. Difficulty in properly counterbalancing the arm, the weight of which would vary from snow and ice forming on same, together with the difficulty of properly compensating the connections for changes in temperature and on account of friction, made the proper operation of lower quadrant signals relatively difficult and a change from the lower to the upper quadrant signal was recommended by the Signal Section in 1907 and has been adopted as a standard by a majority of the American railroads.

With the development of block signaling proceeding from the simple arrangement of a home signal for each block to that of a home signal with a distant signal placed on a separate mast and located something less than braking distance in the rear of the home signal, and then to the arrangement of two arms on a mast comprising a home signal for the block immediately in advance and a distant signal for the next home signal in advance, a simple and satisfactory arrangement of arms was perfected and generally used where automatic block signals were installed. This arrangement of a home and a distant arm on one mast was not well adapted for use at interlockings where there were two or more arms for one or more diverging routes and it was desired that a distant arm be provided for each home signal in advance on each of the diverging routes. This sometimes resulted in as many as five arms being used on one mast, a home, a distant, a home, a distant and a home arm, an arrangement that was complicated from the multiplicity of connections required and the difficulty of enginemen correctly reading the indication displayed. As a result the three position signal was developed, which would serve as a home or stop signal when the arm was in the horizontal position giving a « Stop » indication; as a distant or approach signal when the arm was in the 45° position, above the horizontal giving an « Approach prepared to stop at next signal » indication, and as a clear signal when the arm was in the 90° or vertical position giving a « Proceed » indication. With the one arm, three position signal displaying the same indications as the two arm home and distant signal it is evident the terms « home » and « distant » as applied to a three position signal lose their significance and in consequence the names given signals by the Standard Code are based on the indication displayed and not on the form and arrangement of arms.

The home and distant arrangement is less desirable than the three position signal because the former operates in but two positions and of necessity one of the indications displayed by the home and distant signal is to a certain extent conflicting, in that while the home arm indicates proceed the distant arm gives a modifying indication, restricting the right conveyed by the home arm. With the home and distant arrangement it is not usual at interlockings to provide a distant arm on each mast with a home arm, and in consequence a distant arm is often made to indicate for two or more home signals located in advance, an advance

signal being, so far as the indication of a distant signal is concerned, a home signal. The fact that a distant arm is not provided for each home signal requires that an engineman correctly read each indication, determining whether given by a home or a distant signal and whether or not a distant indication has been or is to be received before arriving at the next home signal. With three position signals each indication is complete in itself and an engineman acting on the indication displayed by the signal the train is approaching does not have to remember if it is modified or affected by the indication of a signal or signals in the rear. For this reason three position signals give more complete and desirable information than two position signals and are preferred not only for the better indications displayed but for the simple and efficient mechanisms and controls provided for their operation.

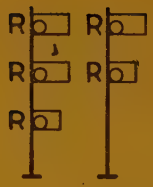
So decidedly is the three position signal to be preferred to the two position, that most enginemen after running in three position signal territory ask for, and as far as may be, demand that two position signals be changed to the three position type. An engineman familiar with and running in three position signal territory finds the two position signal inadequate and undesirable, from the fact he thinks and acts in accord with the simpler and more complete indications of three position signals. The engineman will do his thinking in terms of three position signaling just as will a person knowing two or more languages, think in the one he knows best.

With three position signals coming into general use the American Railway Association in 1915 revised the Standard Code to include the three position aspects and indications so that uniform practice might prevail. Owing to the terms home and distant not being applicable to three position signals and the fact it was undesirable to use more than three arms on a mast, the scheme previously used of route signaling for interlocking signals was given up as inadequate and impracticable of correct application for most situations and the indications of the Standard Code for three position signals denote the speed that may be run and not the route. In other words, the signals of the Standard Code indicate what is required of the engineman and not the route that is set in advance of the train.

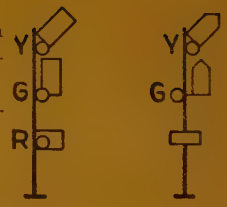
With speed the basis on which the indications prescribed by the Standard Code are arranged it follows that on a three or more track road where indications for three speeds are required; *viz.* high, restricted and slow, signals with a maximum of three arms are advisable. For a double track road where indications for but two speeds, high and slow, are required, a system having but two arms is sufficient and all that need be used. The Standard Code arrangement of aspects for three speed signaling have three arms, and for two speed signaling, two arms, as shown in figure 1. Signals with square end arms and with lights vertically arranged are interlocking signals, unless provided with a number plate, in which case the signals are automatic. Signals with pointed end arms, the lights diagonally arranged and having a number plate, are automatic signals.

With three position signals in use and the indications given by the position of an arm, or by positions occupied by two or more arms, or by the color of two or more lights displayed in combination, it follows that the arms and lights which give an indication for a given track must be arranged on the same mast and this mast must bear a definite relation to the track for which the signal gives an indi-

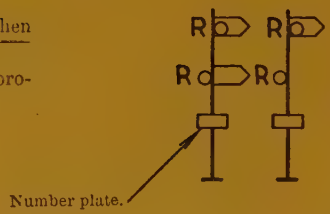
Indication : Stop.
Name : Stop signal.



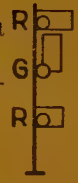
Indication : Approach next signal at restricted speed.
Name : Approach restricting signal.



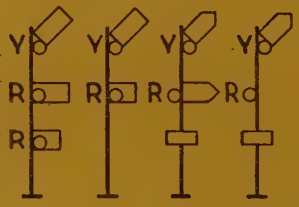
Indication : Stop; then proceed.
Name : Stop and proceed signal.



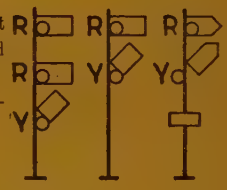
Indication : Proceed at restricted speed.
Name : Clear restricting signal.



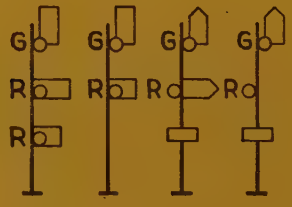
Indication : Approach next signal prepared to stop.
Name : Approach signal.



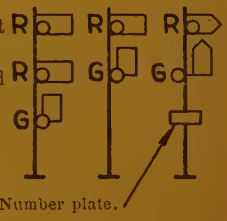
Indication : Proceed at slow speed, prepared to stop.
Name : Slow speed signal.



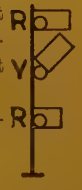
Indication : Proceed.
Name : Clear signal.



Indication : Proceed at slow speed.
Name : Clear slow speed signal.



Indication : Proceed at restricted speed prepared to stop at next signal.
Name : Restricting signal.



Note. — Aspects having square end arms and vertical lights represent interlocking signals, except when provided with a number plate. Aspects having pointed end arms, diagonal lights and a number plate represent automatic signals. Colors for night signals are not prescribed by standard code.

Fig. 1. — Uniform system of signaling, aspects of standard code, American Railway Association.

cation. With the arrangement of all arms of a signal on one mast the simplest possible aspect is provided for each indication, and there is the least possible chance of an engineman not reading correctly the indication displayed, or acting on the indication of a signal other than the one for the track on which the train is running.

Signals are located, as far as is practicable, on the right of the track governed as viewed from an approaching train, as in this position they are in better view of the engineman who occupies the right side of cab. Where there are more than two tracks, and signals cannot be located adjacent to track governed, bridges on which signals may be put are preferred to bracket masts as giving more definite and distinctive relation between each signal and its track. It is undesirable that signals be placed on a bracket mast when the mast has to be put on the left of fireman's side of track where the view of the signal is lost by the engineman when 200 or 300 feet or more away from the signal.

In the adoption of a system of signals for a given section or division, it is highly desirable, as a matter of good practice, the signal aspects be uniform to the end that an engineman may promptly and properly determine on viewing a signal that the indication is perfectly displayed. In the day time no difficulty is experienced in determining if the indication is perfectly displayed and because of this it is customary, with automatic signals, to use no more arms than are required to display the indications, while at night there should be two lights if diagonally arranged, and if vertically arranged two or three as may be the standard for the section. With the aspects uniform for the section, dependence may be placed on the engineman to recognize when an aspect is imperfectly displayed and to act in accord with the requirements of the Standard Code Rule 27, which reads — « A signal imperfectly displayed must be regarded as the most restrictive indication that can be given by that signal. »

While uniformity in aspects is desirable as a matter of good practice and to make possible the imposition of proper discipline, it is just as desirable the aspects used for the « Stop; then Proceed » indication be such that the engineman may readily and correctly determine the character of the signal and the proper action to be taken. By reference to the chart, figure 1, it is to be noted that the signals which display the « Stop » indication have square end arms and the ligths are vertically arranged while the signals that display the indication « Stop; then Proceed » have pointed end arm or arms, and the lights are diagonally arranged. With the form of the arm and the arrangement of lights determining the character of the signal, it follows that so far as the lights are concerned, each signal must have not less than two, while of arms it is necessary that signals having square end arms should have for signals of a given section or division the same number of arms as of lights. With the automatic signal that has pointed end arms no more arms need be provided than are necessary to give the indication, the pointed end of the arm being sufficient distinction in daylight to indicate the character of the signal. With the pointed end arm signal it is therefore customary and good practice, while providing two lighs diagonally arranged, to use but one arm, unless two arms are required to give the indication, the lower diagonally arranged light of the one arm signal being merely a marker light.

Practice in the colors used for night signal indications in America has not been standardized, although the matter

was considered and very nearly acted upon by the American Railway Association in 1915, at the time the last general revision of the Standard Code was made. In early days white was used to indicate « Proceed », green for « Approach next signal prepared to stop » and red for « Stop ». In view of the comparatively frequent breakage of a colored roundel, with the resulting display at night of an improper « Proceed » indication when the arm was in the horizontal position, a number of roads about the year 1896, when a fairly satisfactory yellow glass was developed, changed from the use of white to that of green for « Proceed » and to yellow for the « Approach » indication with red as formerly for « Stop ». While a few large roads are still using white for « Proceed » the majority have changed to green and with satisfactory results.

In view of the greater safety in operation and the desirability of uniform colors for night signals being used by all roads, it is hoped the American Railway Association, will, in the near future, incorporate in the Code the colors now generally used and put the ban of its disapproval on the use of white for the night clear signal indication.

While the colors red, green and yellow are satisfactory, there is great need of a fourth by which additional indications may be displayed, but up to the present a color of sufficient intensity and distinguishability has not been developed. For a short distance view a purple glass has been developed which is largely used to give the « Stop » indication of a dwarf signal which displays indications for a reverse movement on a main track, for a movement from a siding to a main track, or for movements on sidings only, it being most desirable on a two or more track road, that an engineman running with the current of traffic should not see and possibly be confused by the red lights of dwarf signals, the indications of which do not apply to trains running with the current of traffic. The purple light is visible with fair distinctness at a distance of 1 000 feet and is amply sufficient at less distance for the purpose for which used.

From the use of purple for the « Stop » indication of dwarf signals for reverse movements, the practice of a number of roads in the color used for night signal indications has advanced to the reservation of red and green for main track switches and yellow and lunar white for switches in sidings or yards. By so using the colors named, an engineman of a main line train is not burdened with the necessity of determining the position of switches that are on sidings and do not affect the movement of the train. As used on a number of roads the lights for main track switches show green when switch is set for main track and red when set for diverging route. For other switches the lights show lunar white when set for straight track or route and yellow when set for diverging route.

With the indications given by colors, it is essential the amount of light used and the color density of glass be such that light of proper color intensity will be displayed. Yellow at a distance shades off to a white, while close up and particularly in a mist or fog, appears to approach closely to the red. In order that there might be some assurance on the part of the roads that glass of proper color density be procurable and for the manufacturers that the product made would be satisfactory, the American Railway Association has adopted a standard maximum and minimum density for each roundel or lens used for signal purposes. The photometric scale by which the color density is measured is an arbitrary one

agreed to by the Railroads and the manufacturers.

While a roundel or lens may come within the requirements as to color density, it should be borne in mind it is highly desirable the glass be of quality that will transmit a maximum of light. The recently developed « high transmission » glass for the colors of red, green and yellow has been found to give an increased efficiency approximately of from 15 to 20 % in the amount of light transmitted over that of the glass previously obtainable, and in consequence it is now being generally used for signal purposes. In order that the light of a headlight will not be reflected back from the flat surface of a roundel, thereby causing to be displayed a phantom light, the standard roundel is now made in convex form, as shown in figure 2, so that any light reflected from the surface appears merely as a line and may not be mistaken for the light from the signal lamp.

Summary for discussion.

1° Should semaphore signals project from the mast towards or away from the track as viewed from an approaching train?

2° In which quadrant, the upper or the lower, may semaphore signals best be operated?

3° Is not the three position signal more distinctive and less likely to be misread than the two position signal?

4° How may signals for a given track be best arranged, on one mast vertically with one arm above the other, or with each arm on a separate mast with the arms in the same horizontal plane?

5° Should not the signal aspects be uniform for a section or division to enable the engineman to definitely determine if an indication is perfectly displayed?

6° Is it not best to have the signals indicate permissible speed rather than the route?

7° Will not the uniform system of signaling shown in figure 1, be adequate for and satisfactorily meet the requirements of practically all situations on roads of one or more main tracks and for small, as well as large stations or terminals?

8° Are not signals with square end arms and vertical lights of such difference from signals with pointed end arm or arms and lights diagonally arranged as to enable an engineman to correctly determine the character of the indication displayed?

9° Is it not advisable with dwarf signals that give indications for reverse movements on main lines that purple instead of red be used for the display of the « Stop » indication?

10° Is it not good practice to reserve the use of the colors of red and green for the night indications of main track switches and use other lights for night indications of switches in yards and sidings?

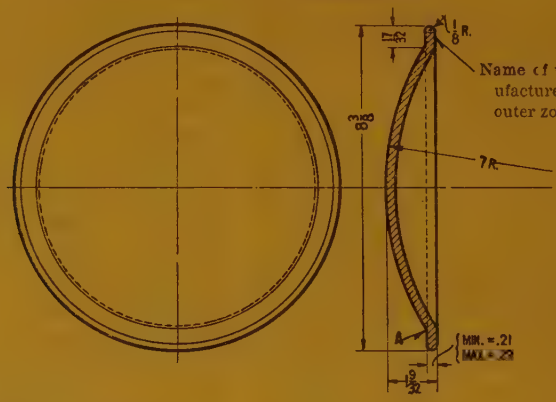
11° Is it not advisable that roundels be of convex form to insure against the display of a phantom or reflected light?

Principles of signaling for lines with dense traffic and for large stations.

The above subject, from the standpoint of American practice, must be considered as referring to different systems of signaling, in that in America, with the exception of a small mileage on a few roads, where the controlled manual block system is still in use, lines having dense traffic are equipped with automatic block signals and protection, additional to that given by the automatic block system, is not regarded as necessary or desirable. For

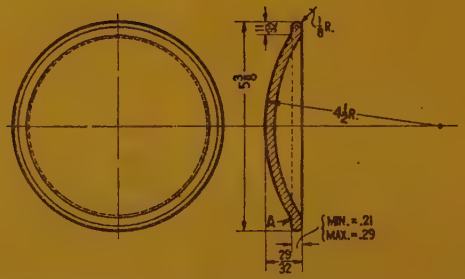
large stations interlocking signals are used. On main tracks away from large stations where traffic is dense it is usual to interlock the main track switches for the protection of crossover and switching movements, but these interlockings are

8 3/8 convex roundel high transmission glass.



Notes.

Scale and all dimensions are given in inches.
Reinforcing bead may be used at « A ».



5 3/8 convex roundel high transmission glass.

Diameter.	Reference numbers for size and colors.					
	Red.	Yellow.	Green.	Lunar white.	Purple.	Blue.
5 3/8	14141	14142	14143	14144	14145	14146
8 3/8	14147	14148	14149	141410	141411	141412

Fig. 2. — Roundels for signals.

not so close together that intermediate block signals may be manually controlled from such stations and dependence for safe block working is placed on the operation of automatic signals. Of the 275 000 miles of road in the United States, 1 672 miles are protected with the controlled manual system; 61 405 miles with

the manual block system and 40 065 miles with the automatic block system.

The manual block system, owing to the high wages paid signalmen for the operation of the signals and to the comparatively slow manuel working secured, is regarded as desirable only for sections which have a comparatively light traffic. Dependence for safe working with the manual block system rests entirely with the signalman, and no check in the form of a lock or other device is provided to control the operation of the signal as with the controlled manual system, nor is track circuit control provided as with the automatic system. The protection secured by the use of the manual is much less than with the automatic system and is so restricted in its method of operation the manual system is not regarded as adequate for the protection of a dense traffic.

With the automatic system the signals are power operated and their operation is controlled by track circuits. The track circuit has been found to be the most reliable agency for the control of signals and practically all large signal installations, both block and interlocking, are dependant for safe working on the proper operation of the track circuit. The successful results obtained with the track circuit in America are largely due to the weight of cars, empty as well as loaded and to the use of all metal wheels, conditions which are essential to the proper shunting of the track circuit relay.

With the track circuit developed to give reliable working and with the track circuit relay controlling the operation of automatic signals directly or by other circuits, it is merely a matter of locating signals a minimum distance apart, to secure that arrangement of the automatic system that will permit the running of a maximum number of trains in a given time. The signals of such a system must, of course, be provided with the number of arms and lights to display proper indications for blocks of the length decided upon.

Owing to the time lost by trains running at slow speed through a block when the signal is out of order and displaying a « Stop; then Proceed » indication it is usual, with automatic signals, to restrict the length of block to approximately two miles where the track is level and for the average installation where the track is level the signals are spaced to make the block approximately one mile in length. The minimum length of block, where the signals are of the single arm, three position type with marker light, should be the distance in which a train may be stopped when running at the maximum speed allowed and the brakes when in proper condition are of a minimum braking efficiency. That this must be so is obvious, from the fact that each train is protected in its rear by a signal displaying a « Stop; then Proceed » indication and an approach signal, displaying the indication « Approach next signal prepared to stop », and as it cannot safely be assumed that under all conditions of weather or causes that may obscure the view of the signal the engineman may see the approach signal far enough away to act on the indication before arriving at the signal, it is necessary the approach signal be located braking distance away from the signal at which the stop must be made.

With the signals spaced braking distance apart, the signals may be said to give a two block indication, for when a signal is in the 90° position displaying a « Proceed » indication, the block between this signal and approach signal must be clear, as also the block between the approach signal and the stop signal. With the signals arranged to give indications

for two blocks, trains running at speed are in reality spaced a greater distance apart, for in order that the engineman may safely run his train at speed it is necessary the signal change to display the « Proceed » indication while the train is some distance in the rear of the signal. Whatever the distance, the engineman must be in the rear of the approach signal to observe it change, and as under the average conditions of a dense traffic this distance is very nearly a block length, trains running at speed are spaced this distance apart in addition to the length of not less than the two blocks which exists between the rear of a train and the third signal in the rear which displays the « Proceed » indication.

With the minimum spacing between trains running at speed under two block indications being in excess of two blocks and practically three blocks in length, it is necessary where trains must be run at speed closer together than this the signals have to be differently arranged and it was for the purpose of providing for a reasonable maximum traffic that the Standard Code was revised by the American Railway Association in 1915 to include the aspects by which indications for three blocks might be displayed and thereby give its approval to the use of a system of signaling with which it would be possible to safely operate trains at speed with the blocks of less length than the braking distance. Where indications for three blocks are given a train will be protected in its rear by signals displaying the indications shown in figure 3. For purpose of comparison the arrangement where indications for but two blocks are displayed is also shown.

In order that safe working may be assured with the signals arranged to give three block indications it is practically necessary the rate of speed authorized by the approach-restricting-signal should be prescribed in the special instructions of the time-table and must be such that a train may be stopped in the distance between the approach-restricting-signal and the stop signal.

For the blocking of trains of the traffic density existing in America, except for certain electric traction lines operating in cities, the arrangement of automatic signals displaying three block indications has been found to satisfactorily meet the situation permitting a reasonable minimum spacing between trains. An arrangement of signals by which a greater number of trains may be run in a given time than is permitted with the three block indication system, it has not as yet been necessary to provide.

Summary for discussion.

1° Is it not advisable to limit the length of automatic blocks to reduce to a minimum time lost by trains moving slowly through a block, the signal for which is displaying the « Stop; then Proceed » indication?

2° With automatic signals arranged to give indications for two blocks may the approach signal be properly located nearer the stop signal than the braking distance for trains that are run?

3° With the three block indication scheme may the approach-restricting-signal satisfactorily be located nearer the stop signal than braking distance for trains that are run?

4° Are not the indications displayed by automatic signals which are located braking distance apart adequate for and make possible the running of a maximum number of trains?

5° Is it desirable that aspects be devised by which indications for four blocks may be displayed and permit the running of a

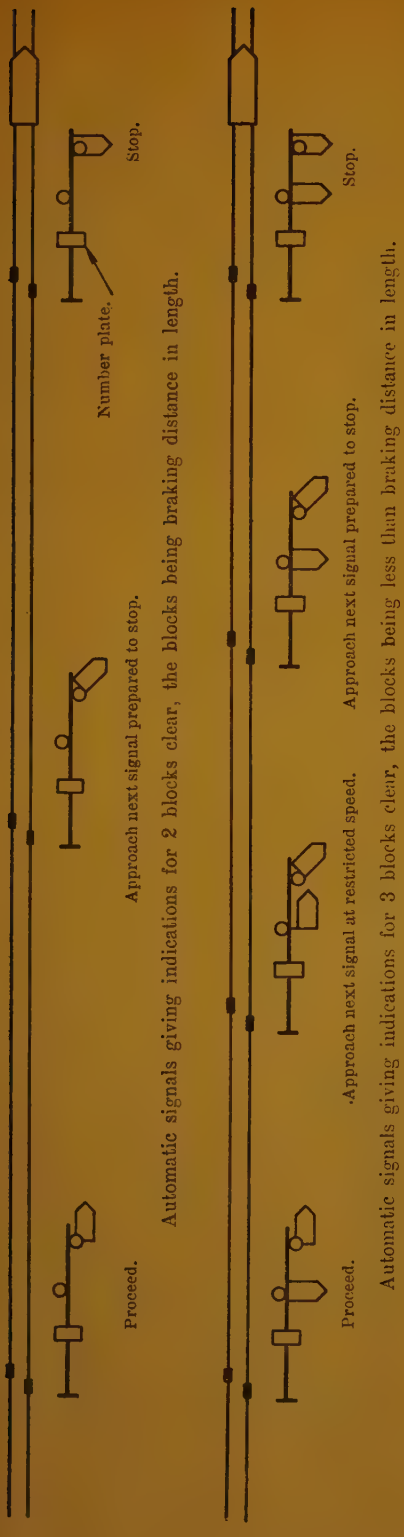

Proceed.
Approach next signal prepared to stop.
Number plate.
Stop.
Automatic signals giving indications for 2 blocks clear, the blocks being braking distance in length.
Proceed.
Approach next signal at restricted speed.
Approach next signal prepared to stop.
Stop.
Automatic signals giving indications for 3 blocks clear, the blocks being less than braking distance in length.

Fig. 5.

greater number of trains in a given time than is practicable with the three block indication system?

Principles of signaling for large stations.

On main tracks outside of large stations the number of trains that may be run on one track in a given time is dependent upon the spacing of block signals, but at large stations or terminals the maximum traffic that may be handled is a matter of the location and control of interlocked signals. In order that trains may be moved with safety in large stations an interlocking must be installed to insure that the switches and signals will be operated in such predetermined and proper order that not two signals may be cleared at the same time authorizing movements on routes which conflict. The facility with which movements may be made through a large station depends principally on the track layout and this should be so arranged that signals may be placed in locations closest to the fouling point of each switch or group of switches in order that the route will be held for the shortest practicable time before and after the passage of a train.

The number of arms and lights used on a signal of a large station interlocking may be the maximum authorized by the Standard Code, but generally, from the lack of clearance and impracticability of providing a good view of each signal from an approaching train, as well as to the fact that the speed must be restricted, owing to the comparatively short braking distance between signals, one arm signals of the three position type may be made to give the indications required to permit full use of tracks by trains running at moderate speed while two arm signals may be made to display the indications needed at almost any large terminal to

permit trains to run at the speed which the track layout makes possible.

From experience with existing installations it has been demonstrated that for large terminals interlocking signals having two arms may be arranged to give all the indications required to enable the enginemen to take full advantage of track facilities provided and insure a maximum of train movements. The two arm signal so used would display the indications prescribed by the Standard Code, the upper arm being operated in three and the lower arm in but two positions. The upper arm when in the 90° position would indicate a movement may be made passing two signals on the route set and that the track was unoccupied, the lower arm when in the 45° position that a movement might be made on the route set, from but one signal to the next and the track may or may not be occupied. The upper arm in its working would be controlled by track circuit and give block signal protection, while the lower arm moving only to the 45° position would not be so controlled and would in reality display a permissive indication for a movement to a section of track that may be occupied.

Where the track arrangement is such that high signals may be located at points where there will be no difficulty in determining the indications displayed or the particular track for which the signals give an indication, they are preferred to dwarf signals but as it is seldom high signals may be placed where desired, owing to lack of clearance and the confusion that results from other signals being observed in the immediate background, dwarf signals will in many cases better meet the requirements and have been used at some of the most recent installations.

Where there is insufficient clearance for two arm dwarf signals, one arm signals have to be used and should be made three position. The dwarf signal arm when in the 90° position indicates « Proceed at slow speed » on the route set, which would be the one on which the next signal in advance is in the 45° or 90° position and the track clear to the third signal in advance, block protection for the movement being given by the signal when the arm is in the 90° position. If the next signal in advance was not in the 45° or 90° position or the track was occupied, the signal might then be moved only to the 45° position and would display the indication « Proceed at slow speed prepared to stop ».

With interlockings of large stations it is practically necessary that certain electrical controls be provided to insure the integrity of the route until each movement has been completed. It is also desirable as an operating facility that an indicating chart be provided to show to the train director the approximate position of each train and that lever lights be installed to show to the signalman whether or not the lever controlling a switch may be operated. These electrical controls are known as approach, switch and route locking and are arranged to hold the route for an approaching train from the time the signal is cleared until the head end of the train has passed the signal and run on track circuit of the first switch of the route; to keep locked the levers controlling all the switches of the route until train has passed over each track circuit of route governed by the signal, and to release the locks on the levers of the switches of each track circuit permitting a change of route immediately after the rear end of train has passed off and is clear of each track circuit.

As a matter of efficiency in operation, it is desirable the levers controlling

the several operated units be so arranged in the interlocking machine that a signalman may operate a maximum number of levers. The desired results may be secured by numbering the operated units in as small groups as practicable; first, the signals governing in one direction, next the switches and then the signals of the group governing in the opposite direction. While often requiring considerable study the numbering of the levers is of such importance from an operating standpoint that nothing less than the best possible arrangement should be regarded as satisfactory.

While practice differs materially as to the number of switches or signals that may be controlled by one lever, it is believed that the arrangement where each operated unit is controlled by a separate lever is more efficient and economical from an operating and maintenance standpoint than where two or more units are operated by a single lever which is the arrangement most generally used.

Interlockings at most of the large stations in America are of the power operated type, it seldom being practicable to obtain clearance for the connections of a mechanical plant, nor practicable to operate by mechanical means the units which so frequently have to be located relatively long distances from the signal station. With a power operated machine the units are operated so much more quickly than by the hand operation of mechanical connections it is practically necessary as a matter of efficiency that a power interlocking be provided for a large station.

Summary for discussion.

1° For large stations will not two arm signals, the upper arm working in three positions and the lower arm in two positions provide all the indications necessary to permit full and free use of tracks and lessen the chance of an indication being incorrectly read by an engineman?

2° Where at large stations the clearance is such that one arm signals only may be used may not these, when three position, be made to display indications which will permit of the full use of tracks by trains running at moderate speed?

3° Are not dwarf signals to be preferred for large terminals where the view of a high signal will be confused with that of other signals in the immediate background?

4° If full advantage is to be taken by trains of the track facilities provided is it not necessary that the signals of a large interlocking be made semi-automatic; that is, be controlled by track circuits in addition to manual operation, to provide block protection for train movements?

5° Is it not desirable that approach electric locking be provided to prevent the signalman taking away from an approaching train a clear signal indication and attempting to change the route before the train has stopped?

6° Are not electric switch and route locking controls to be preferred to detector bars and provide the most effective and complete protection that has as yet been devised to prevent the changing of a switch under a train?

7° Is it not advisable the levers of an interlocking machine be numbered in such selected small groups of operated units as will require of the signalman the least amount of walking?

8° Is it not advisable as a matter of economy in installation and maintenance, reliability in working and efficiency in operation that a power instead of mechanical interlocking be installed at large stations?

Forms of day and night signals.

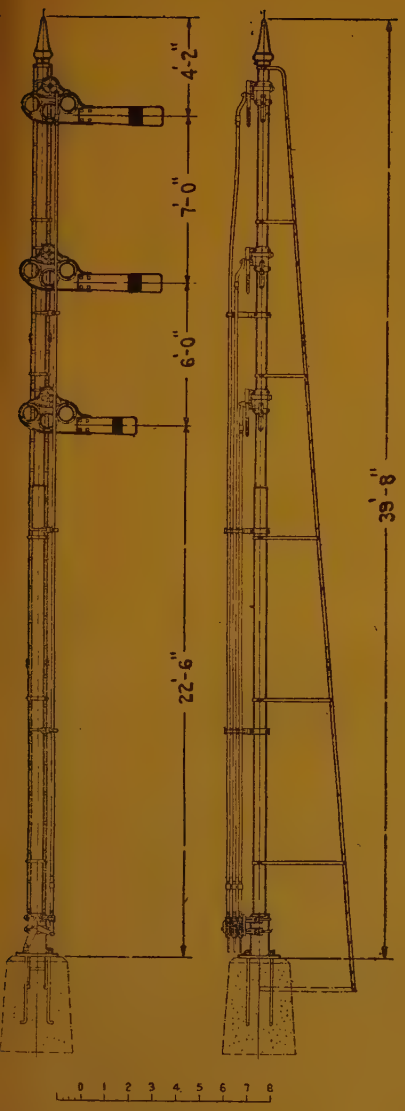
In America standard forms of semaphore signals have been adopted by the American Railway Association for interlocking and also for automatic signals, and are in use on practically all roads. Interlocking signals and automatic signals which display the « Stop » indication have square end arms and lights vertically arranged. Automatic signals which display the « Stop; then Proceed » indication have a pointed end arm or arms and lights are diagonally arranged. The standard design of three arm, three position signal with square end arms, with lights vertically arranged and having mechanical connections is shown in figure 4. The standard design of two arm, three position automatic signal with pointed end arms and lights diagonally arranged is shown in figure 6. Signal blades of standard dimensions are shown in figure 9, the blades being colored in accord with the standard of each road. Blades are now generally made of sheet steel enameled, and with infrequent cleaning the color is satisfactorily retained for a comparatively long time.

The three position semaphore spectacles, standards of the American Railway Association, and used by all roads are shown in figure 10 for the spectacle with light on right side of mast, and in figure 11, for spectacle with light on left side of mast. As the arm of a power operated signal mechanism is returned to the horizontal position by gravity, it is essential the design of spectacle be such there will be sufficient torque to cause the spectacle to return to the horizontal position with or without a blade, or with a blade of any of the different weights that may be used. The torque curves for spectacle with blades of different weights are shown in figure 12. The standard torque curve for each spectacle with standard attached parts is shown on the drawing of each spectacle.

It is to be noted the torque varies, being at its lowest when the arm is in the horizontal position, at a maximum when arm is at 55° and between these two when the arm is in the 90° position. It is desirable the torque be at its maximum when arm is in the 90° position and to decrease, in proportion to the travel, to that existing when the arm is in the horizontal position, but a practical design with which this preferred torque will be obtained has not been developed. While the torque of the standard spectacle has been found sufficient where, for mechanical connections, one inch pipe is used, it is sometimes found desirable with the designs of power mechanisms to increase the torque over that given by the standard spectacle. This is accomplished by fastening a casting of suitable design to that part of spectacle which will give as nearly as obtainable the increased torque at that point of travel of the arm where the increase is desired.

While the semaphore signal is essentially a day signal and is provided with lights by which the indications are displayed at night, the difficulty and expense of securing desired reliability of working lead to the successful development of light signals which, without distinctive form, give the indications for day as well as for night by color, by position, or by both color and position.

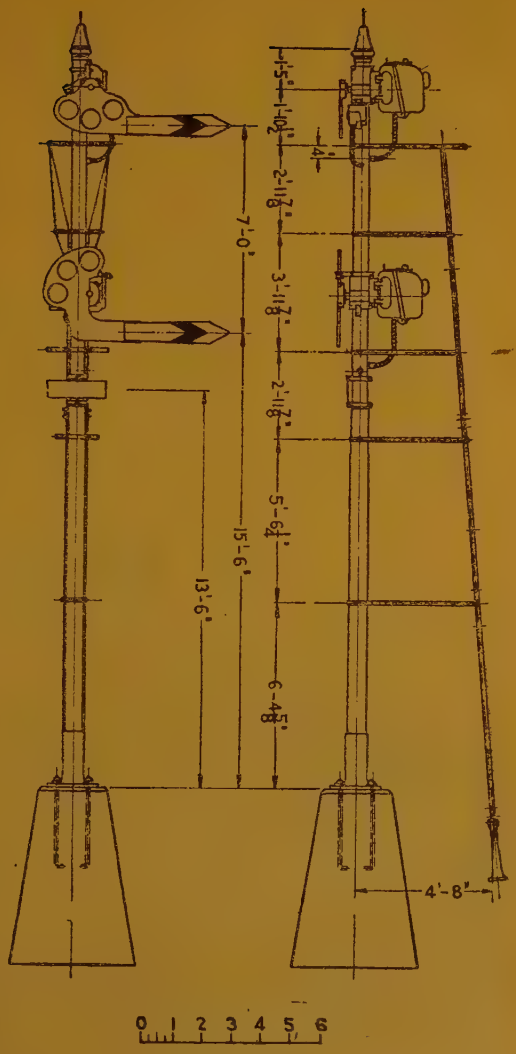
Not only are light signals more reliable and economical in their working, but are so much more distinctive than semaphore signals they are being installed in large numbers on many roads and it may safely be predicted that in the reasonably near future the light signal will be regarded as the preferred type.



Scale of feet.

Three-arm mechanical ground signal.

Fig. 4.



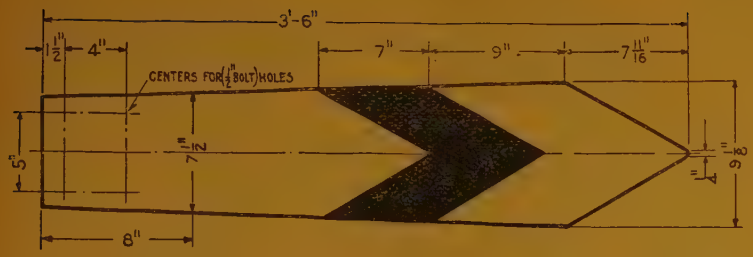
Scale of feet.

Fig. 6. — Two-arm, three position upper quadrant automatic signal having pointed end arms, lights diagonally arranged and a number plate.

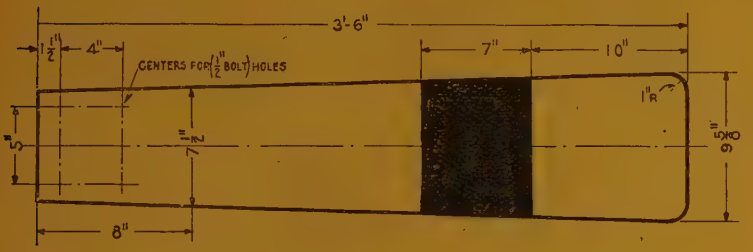
Fig. 5. — Two-arm interlocking signal, upper arm semi-automatic working in three positions, lower arm mechanically connected and working in two positions.

Fig. 7. — One arm, three position, upper quadrant automatic signal with marker light and number plate.

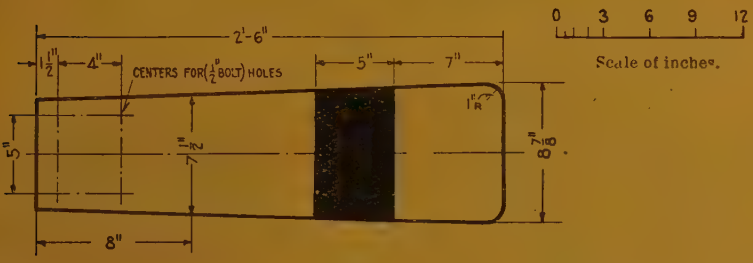
Fig. 8. — Two arm, three position, automatic signal displaying indication : « Approach next signal at restricted speed ».



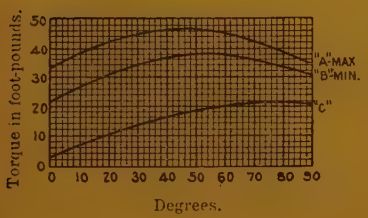
15481 — blade.
Red
with white stripe.
15482 — blade.
Yellow
with black stripe.



15483 — blade.
Red
with white stripe.
15484 — blade.
Yellow
with black stripe.



15485 — blade.
Red
with white stripe.
15486 — blade.
Yellow
with black stripe.



Curves « A » and « B » for blade, spectacle and roundels, 0°-90°.

Curve « C » for spectacle and roundels (without blade and fastenings), 0°-90°.

1. — Blades shall be made of open hearth enameling steel and enameled with not less than three (3) coats of vitreous enamel.

2. — Color back of all blades black.

3. — Unless otherwise specified, blades shall be furnished with fastenings to fit A. R. A. standard semaphore spectacle.

Wind pressure test :

Attach the blade to A. R. A. standard semaphore spectacle; with surfaces of blade, first the front and then the back, parallel to and towards the floor. Apply a load of 60 lb. at the geometric center of that portion of the blade extending beyond the fastenings. During either of the above tests, the blade shall not take a permanent set.

Fig. 9. — Standard semaphore signal blades.

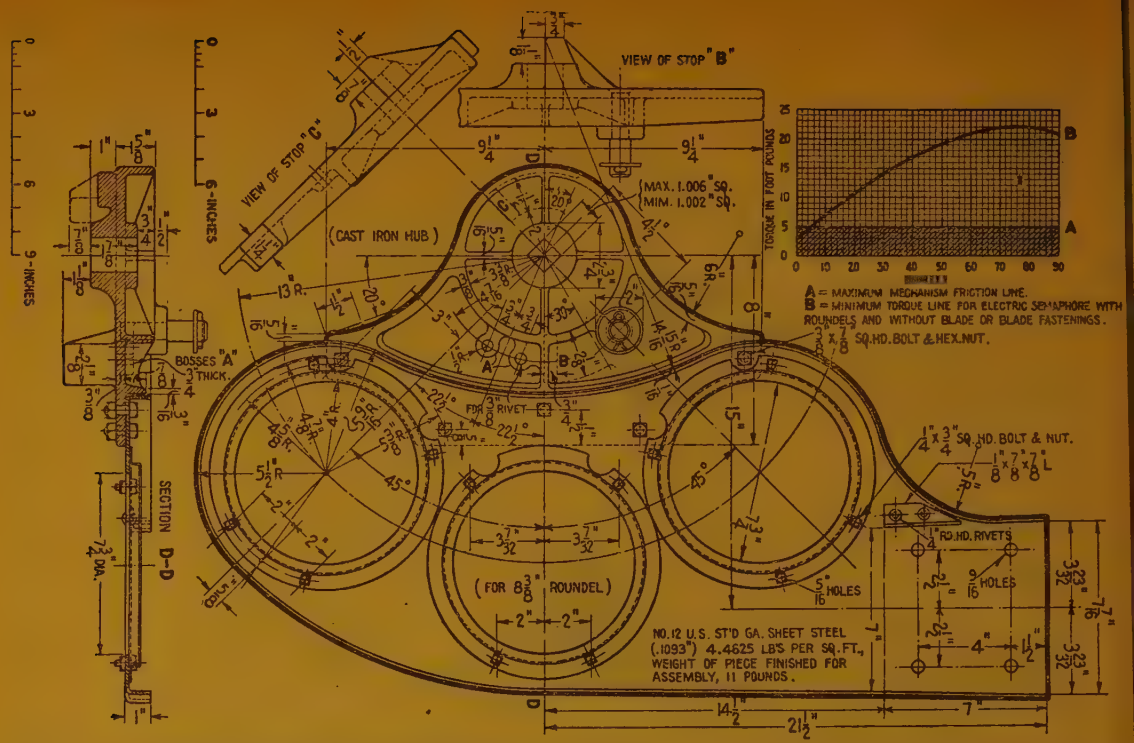

VIEW OF STOP "B"
VIEW OF STOP "C"
(CAST IRON HUB)
MAX. 1.006" SQ.
MIN. 1.002" SQ.
BOSSES "A" 3" THICK.
SECTION D-D
(FOR 8 3/8" ROUNDEL)
FOR 3" RIVET
4 1" x 3/4" SQ. HD. BOLT & NUT.
1" RD. HD. RIVETS
5/16" HOLES
NO. 12 U.S. ST'D GA. SHEET STEEL (.1093") 4.4625 LB'S PER SQ. FT., WEIGHT OF PIECE FINISHED FOR ASSEMBLY, 11 POUNDS.
TORQUE IN FOOT POUNDS
DEGREES
A = MAXIMUM MECHANISM FRICTION LINE.
B = MINIMUM TORQUE LINE FOR ELECTRIC SEMAPHORE WITH ROUNDELS AND WITHOUT BLADE OR BLADE FASTENINGS.
7/8 SQ. HD. BOLT & HEX. NUT.

Fig. 10. — Standard spectacle for three position, upper quadrant signal with light on right side of mast.

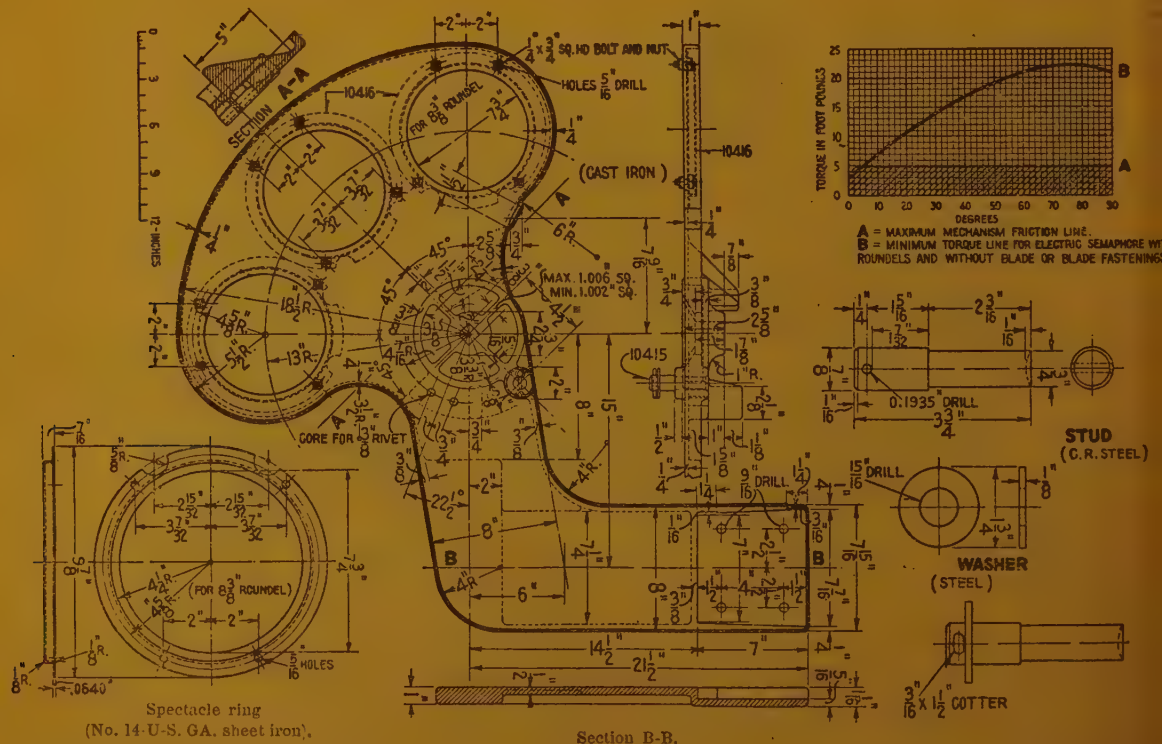
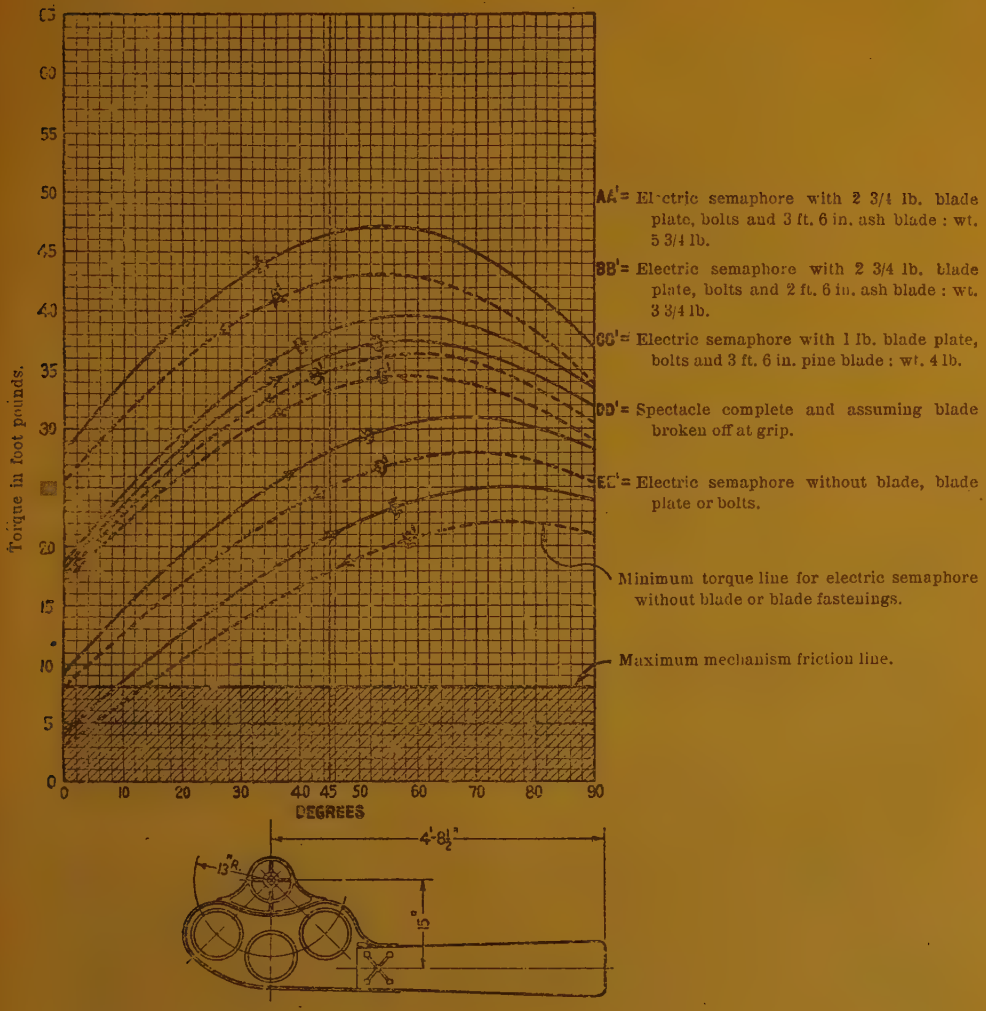

SECTION A-A
4 3/4" SQ. HD. BOLT AND NUT
HOLES 5/16" DRILL
(CAST IRON)
MAX. 1.006" SQ.
MIN. 1.002" SQ.
CORE FOR 3" RIVET
(FOR 8 3/8" ROUNDEL)
0.1935" DRILL
STUD (C.R. STEEL)
WASHER (STEEL)
3/16" x 1 1/2" COTTER
Spectacle ring (No. 14 U.S. GA. sheet iron).
Section B-B.
TORQUE IN FOOT POUNDS
DEGREES
A = MAXIMUM MECHANISM FRICTION LINE.
B = MINIMUM TORQUE LINE FOR ELECTRIC SEMAPHORE WI
ROUNDELS AND WITHOUT BLADE OR BLADE FASTENING

Fig. 11. — Standard spectacle for three position, upper quadrant signal with light on left side of mast.

Note. — Full lines represent torque for spectacle movements 0° to 90° (stop to proceed).

Dotted lines represent torque for spectacle movements 90° to 0° (proceed to stop).



Note. — Spectacle equipped with 8 3/8 inch. roundels and retaining rings in all cases.

Fig. 12 — Torque curves for electric semaphore spectacles.

Fig 13. — Single lens, color light automatic signal, with marker light and number plate.

Fig. 14. — Dead ending of wires on crossarm at a color light automatic signal location.

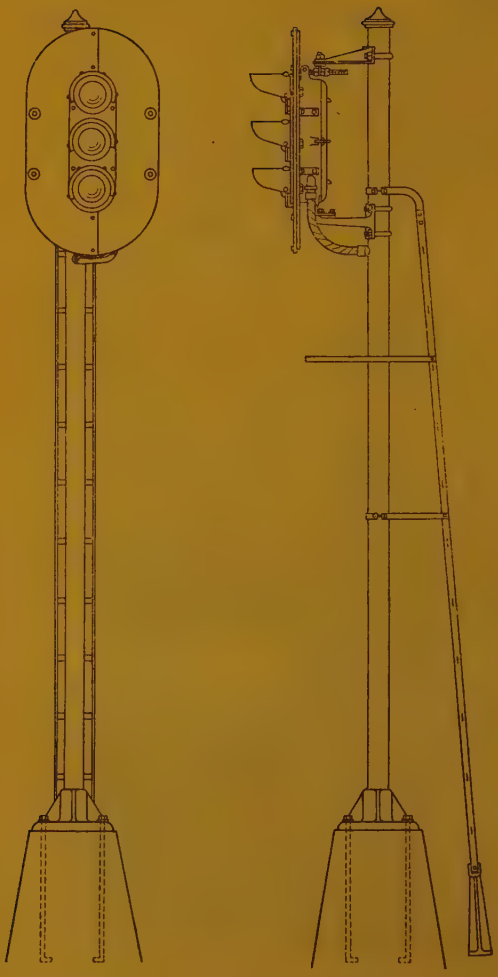


Fig. 15. — Three lens color light signal, vertical arrangement of lenses.

Fig. 16. — Three lens, color light signal, triangular arrangement of lenses.

Fig. 18 — Position color light signal.

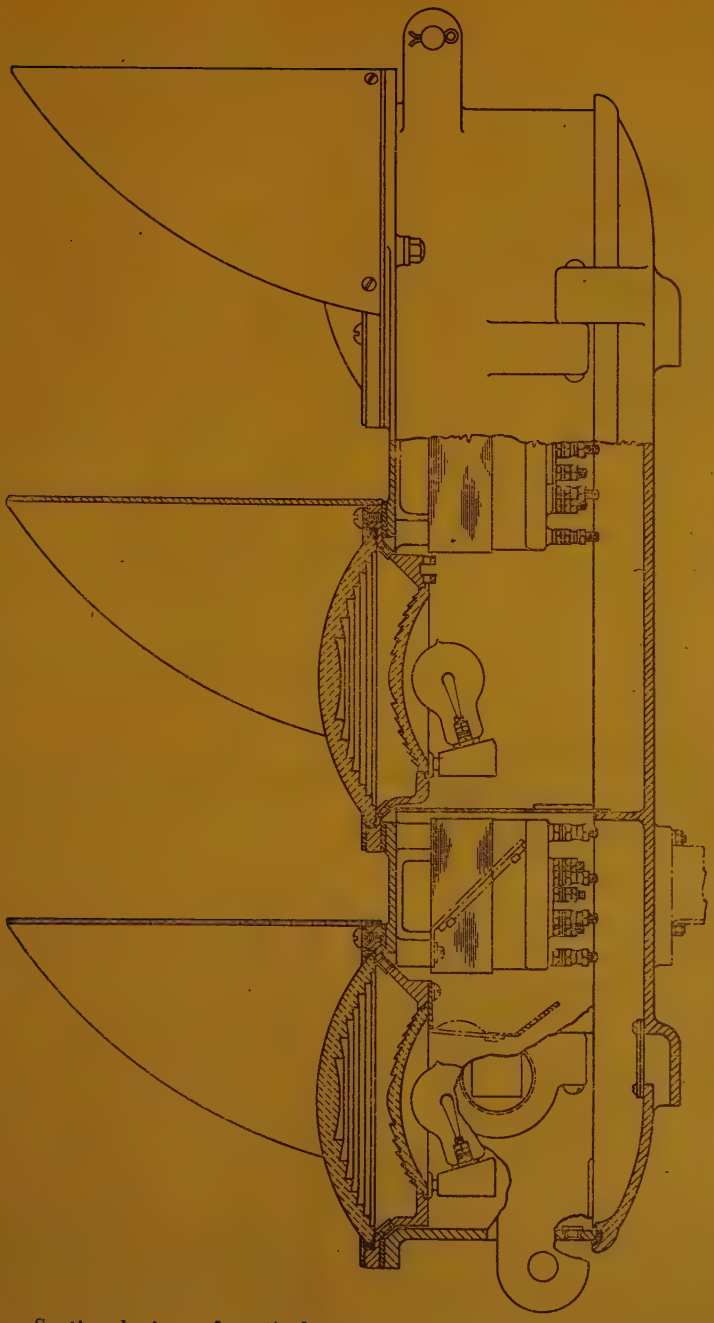


Fig. 17. — Sectional view of vertical arrangement, three lens, color light signal.

An advantage of the light signal in addition to those mentioned, is the comparatively small space which the case enclosing the lens and electric lamp occupies, making it possible to use this signal in places where it is impracticable from lack of clearance or from obstruction to the view to install a semaphore signal.

Fig. 19. — Front view of position light signal showing arrangement of lamp units.

Color light signals are of two general types. With one type a lamp is arranged in the focus of a reflector, the light being reflected through a small colored glass fixed in a spectacle operated by a relay which moves in front of the light the glass of proper color to give the indication. A sectional view of this signal is shown in the *Bulletin of the International Railway Congress Association* of November, 1923, page 1034. The signal as it appears in service with marker light below the light giving the indication and with number plate is shown in figure 13.

The other type of color light signal is that of a case or box divided into compartments with a colored lens ar-

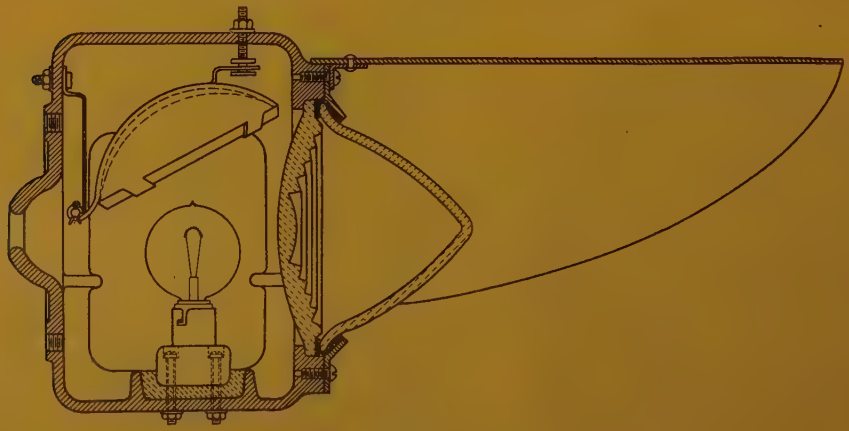


Fig. 20. — Sectional view showing lamp unit assembly of position light signal.

ranged in the side of each compartment, an electric lamp being placed inside of each compartment in the focus of the lens, the required indication being given by lighting the lamp behind the lens that is of proper color. The case in which the several compartments are arranged is usually made in two forms, one with the

lenses vertically arranged in an oval disc, figure 15, the other with the lenses in the form of a triangle, the background of which is a round disc, figure 16. A sectional view of a series of compartments showing arrangement of lamp and lenses is given in figure 17.

Where the indications are given by position as well as by color, the lenses are arranged around a disc as shown in figure 18, the indications being given by lighting the lamps behind the two opposite lenses which are of the proper color and in the required position.

Where the indications of a light signal are given by position only, the lenses through which, for high signals, a slightly tinted yellow light is displayed, are arranged within a circular disc designed to serve as a background, one lens being placed in the center of the disc and the other lenses, as required to give the indications, arranged around the center lens to show, when lighted, any one of as many as four different rows of lights. The general appearance of the disc and arrangement of lamps for the three position signal is shown in figure 19, the opening to accommodate the unit for the fourth position being blanked. It will be noted that by lighting the lights behind any three lenses that are in a row, a line of lights will be displayed in one of four positions required to give the indications; *viz.* horizontal, 45° from the horizontal, up or down, or vertical, these being the positions corresponding to those occupied by a semaphore arm, and with one additional that may not be given by a three position arm. As the indications are given by the position of a row of lights, it is necessary with position light signals that the same number of groups of units be provided as semaphore signals require arms with which to display the indications. If lights are to be displayed in but one or two positions by a group of units representing the arm of a signal, the disc or background provided may be omitted or made of such form as desired. The sectional view of the lens, yellow tinted cover glass and arrangement of electric lamp bulb in focus of lens together with reflector to throw part of the rays downwardly to give a brighter light at a point almost under the signal is shown in figure 20.

Position light signals are now standard on several of the large roads in America and their use will undoubtedly be extended.

While the lighting of the modern electrically lighted signal is superior to that of other types of signals, the principal advantage to be gained by the use of light signals is the practical elimination of most of the causes of wrong working that make it comparatively difficult to keep semaphore signals operating properly. Except for one design of colored light signal using a relay armature to move a miniature spectacle with its colored glasses in the focus of the lens, the light signals have no moving parts, and it is estimated there will, with light signals, be at least 50 % less failures resulting in a clear indication being wrongly displayed than where semaphore signals are used. Not only will there be this greater reliability in the working of light signals but the cost of maintenance will be at least 1/3 less than with semaphore signals. With greater reliability and economy and also efficiency as evidenced by the more distinctive indications given, and the quickness with which the proper indications are displayed, a change from one to another indication being made in less than a second of time, light signals will most probably, in the near future, become the standard signal of most of the roads.

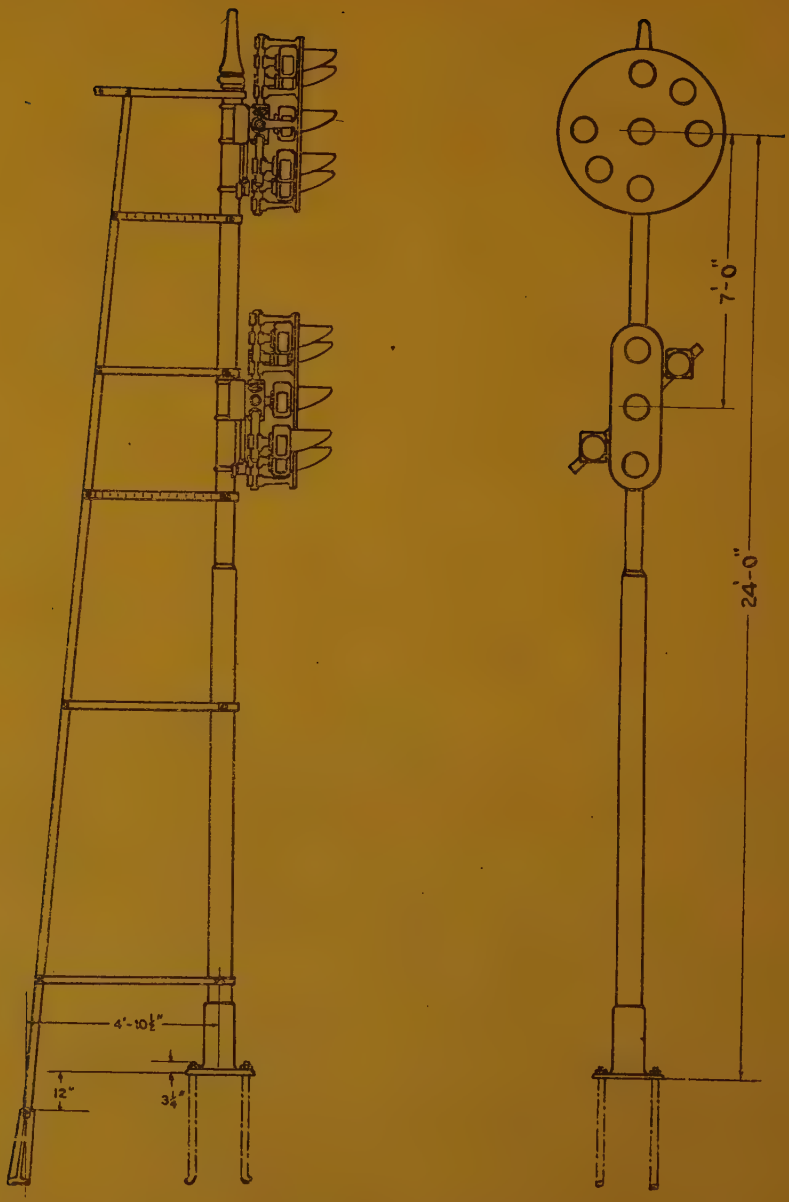


Fig. 21. — Position light signal that may display the indications given by a two arm, upper quadrant, semaphore signal.

Summary for discussion.

1° Is it not desirable the torque of a spectacle with blade be greatest when arm is in vertical position to insure as far as practicable that inertia and friction of parts will be overcome and the arm start to move when the mechanism is released?

[a]Fig. 22. — Three position light signal.

So, also, is it not desirable the torque be lightest when arm is in horizontal position, to require less work on the part of the motor to start the arm in its upperward movement?

2° Now that light signals have been perfected to give efficient, reliable and safe working, is it not advisable light signals be used instead of semaphore signals for renewals and for new installations?

3° Is not the indication displayed by the color light signal so distinguishable that it is unadvisable and unnecessary to

Fig. 23. — Position light signals on signal bridge.

use the additional lights required to give the indication by color and position?

4° In what way may a part of the rays of light of color light signal best be deflected downwardly to improve the indication when viewed from an engine stopped immediately in the rear of and almost under the signal without taking away too much of the light displayed in the direction of an approaching train?

5° With the lightly tinted yellow lights used for the position light signal will not these be visible at a greater distance and also be more distinguishable in fog or smoke than the color light signal?

6° With a suitable background, which is the most distinctive and will the more strongly impress on the engineman the importance of obeying the indication displayed, the position light signal or the color light signal?

7° Which will be the most effective signal for a color blind man, the color or the position light signal?

8° Does the fourth indication, available with the position light signal, constitute a distinct advantage over the color light signal?

Signal lights.

Lamps for semaphore signals have been brought to such state of development that but two standards are in general use in America, one using oil and the other electricity as the source of light. This accomplishment is largely due to the work of the Signal Section of the American Railway Association in the preparation of the designs and advocating the adoption of these lamps by the roads.

The standard oil burning lamp shown in figure 24 is equipped with an oil pot holding 31 ounces and has a burner using a 1/4 inch round woolen wick, which, with oil of proper quality will give a flame about 5/16 inch diameter, from 7/8 inch to 3/4 inch in height and burn for 7 days. However, it is usual to have this lamp attended to twice each week, principally to remove the crust from the wick and insure that the desired height of flame will be maintained. In the extreme northern parts of the country where the maintenance of oil lamps is difficult during weeks of winter weather the lamps of one road have been provided with special pots holding approximately one gallon of oil which, when of proper quality, will burn successfully and require attention but once each month.

The principal requirements of a specification for this long time burning oil, are :

COLOR :

The color of the oil shall be water white and the oil shall remain perfectly clear and transparent when cooled and held at a temperature of 0° Fahr. for ten minutes. When heated in an open vessel to a temperature of 260° Fahr. for eight hours, there shall be no precipitation and only a minimum turbidity.

GRAVITY :

The gravity shall be between 47 1/2° minimum and 48 1/2° maximum Baume.

ACIDITY :

The oil shall be neutral, showing neither acid nor alkaline reaction.

FLASHING AND BURNING :

The oil shall not flash below a temperature of 121° Fahr. in the « Elliott » closed cup, nor burn below 150° Fahr. in the « Tagliabue » open cup, when heated at the rate of 2° per minute and flame applied every 2° beginning at 100° Fahr.

SERVICE :

The oil shall burn in standard lamp 96 hours with flame 7/8 inch high at

Specifications.

1. — Body of lamp shall be made of No. 18 sheet steel tinned.

2. — Rivets shall be used in construction of the body of the lamp for holding parts together.

3. — Handle of lamp shall be No. 4 B. W. G. steel wire.

4. — Door shall have water-shed so arranged as to prevent rain entering the lamp, door shall raise high enough to make the opening six and five-eights (6 5/8) inches.

5. — Lamp shall have top draught ventilation. [ventillation will be tested when required at the factory as follows : « A » wind velocity equivalent to eighty (80) M. P. H. for two (2) minutes. « B » still air temperature one hundred and ten (110) degrees Fahr. for two (2) hours.] The lamp will be rejected if either of the above tests extinguish the flame.

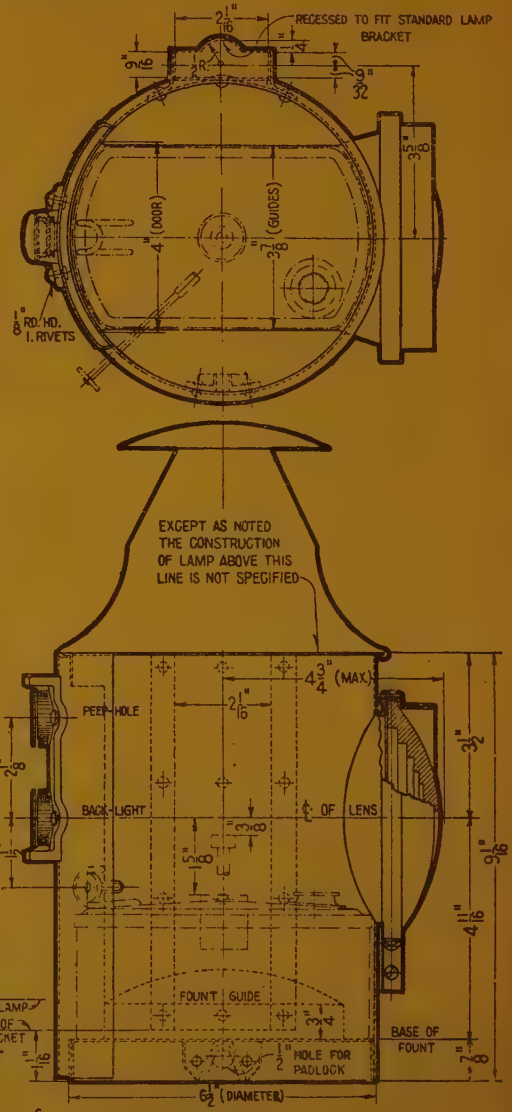
6. — Lens shall be (see reference numbers) inches in diameter with three and one-half (3 1/2) inch focus.

7. — Lens holder shall be arranged so that lens can be easily removed and shall completely encircle the lens.

8. — Socket not to exceed the dimensions of bracket more than one-sixteenth (1/16) inch and be eight (8) inches in depth, recessed to fit standard lamp bracket (R. S. A. 1049).

9. — Back light and peep-hole glasses shall be held in place by (11006) screw retaining rings.

10. — Insect screen shall be provided when specified.



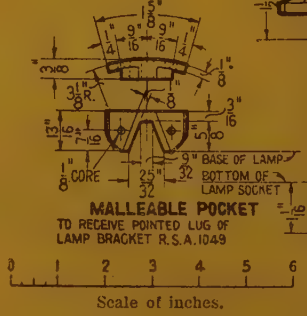

9" BASE OF LAMP
BOTTOM OF LAMP SOCKET
CORE
MALLEABLE POCKET
TO RECEIVE POINTED LUG OF LAMP BRACKET R.S.A. 1049
0 1 2 3 4 5 6
Scale of inches.

Fig. 24. — Oil burning signal lamp.

commencement of test without such incrustation on wick as to decrease size of flame to less than 3/4 inch high at end of test.

While it is specified oil lamps shall have top draft ventilation, so many different designs are in successful use a standard has not been agreed upon or adopted. As the name implies the down draft method provides for the admission of air to the lamp at the top only, a suitable cone being provided in the top of lamp to keep the hot outgoing air separate from the incoming cold air and to deflect the cold descending air, which is practically of the same temperature as the lamp body, against the side of the lamp and prevent the formation of moisture on the lens which will occur if hot air containing products of combustion comes in contact with the cold lens. The success with which the hot air is kept away from the lens will in a large measure determine the extent to which moisture will be prevented from collecting on the inside of the lens. As moisture deposited on the lens will materially reduce the amount of light passing through, it is necessary, if a good light is to be obtained, the draft arrangement be such that the air coming in contact with the lens shall be of a minimum temperature and contain a minimum of moisture.

Owing to the small size of flame of the long time burner it is necessary the draft of the lamp be such the flame be kept steady and not blown out of the focus of the lens, as should this occur no light will be visible from points within the angle of spread of light from the lens. Up to the present the down draft method of ventilation is the best that has been developed for long time burning lamps and the simplest practicable means of maintaining the small bright oil flame in the focus of the lens.

Owing to the comparatively long time the light from the 1/4 inch round wick will burn, the burner to which this wick is adapted, has been given the name « Long time burner » and the oil for use with this burner is known as « Long time burning oil ».

The flame from the long time burner has an average intensity of 3/4 candle power and owing to the comparatively large proportion of flame that comes within the focus of the lens the light given out within the angle of spread of lens is greater than where a larger flame is used with but a small portion in the lens focus. For this reason lamps having long time burners give a better light, use less oil and are less expensive to maintain than lamps equipped with a flat wick and consuming a larger quantity of oil.

The electrically lighted lamp standard with the American Railway Association for use with semaphore signals is shown in figure 25, the case being made of cast iron or other suitable metal. The design of electric lamp bulb, filament and base is shown in figure 26. Lamp bulbs are obtainable with a filament for use with current of either 13½, 12, 10, 8 or 3½ volts, these being the voltages it has been agreed between the Signal Section and the Manufacturers will be standard for future installations.

The design of the attachment with which the lamp socket is fastened to the lamp body has not been decided upon, several different designs being in use. The arrangement finally adopted must provide for the adjustment of the lamp bulb in all directions, making it possible to bring the filament in the exact focus of lens. The manufacturers claim it is not practicable to fix the filament in a

standard position in the bulb and the filament may vary as much as 1/16 inch from the vertical and 1/32 inch from the horizontal position desired.

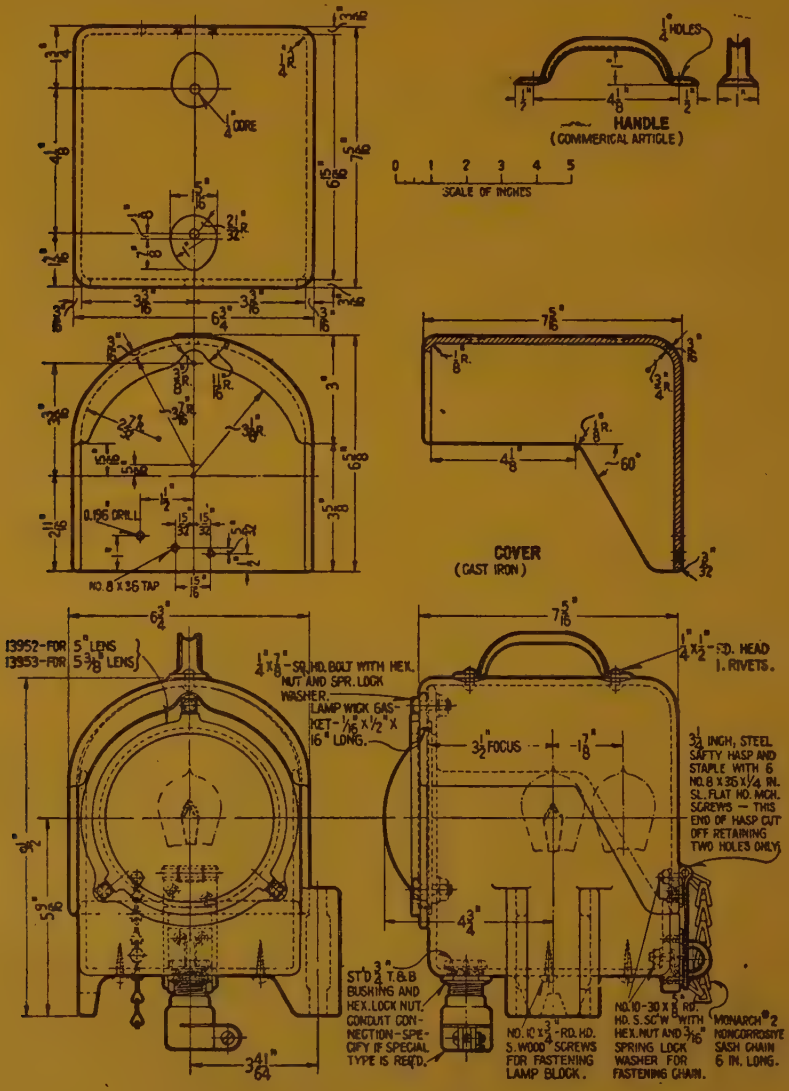
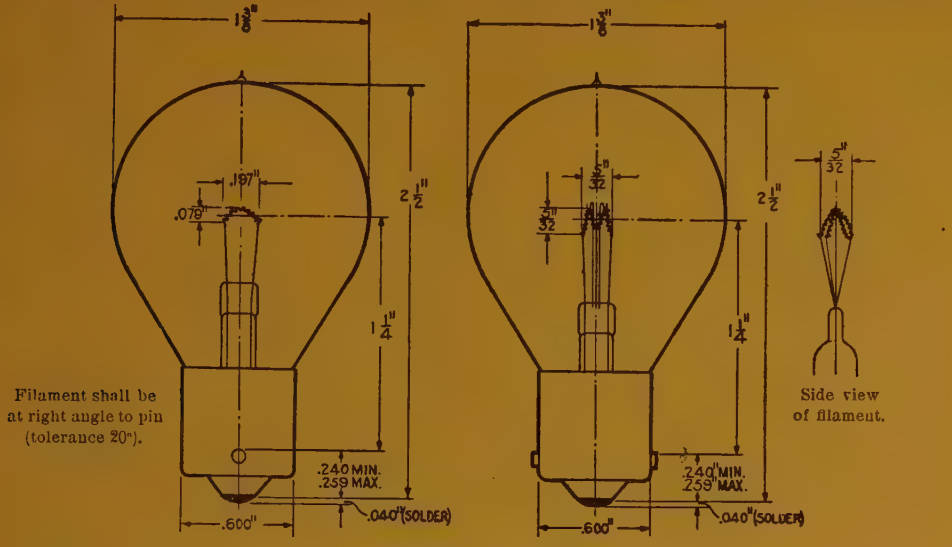

HANDLE
(COMMERICAL ARTICLE)
SCALE OF INCHES
COVER
(CAST IRON)
13952-FOR 5" LENS
13953-FOR 5 3/8" LENS
LAMP WICK GASKET
3 1/2 FOCUS
STD 3/4 T&B BUSHING AND HEX. LOCK NUT CONDUIT CONNECTION
NO. 10 X 1/2 RD. HD. S. WOOD SCREWS FOR FASTENING LAMP BLOCK.
SPRING LOCK WASHER FOR FASTENING CHAIN.
MONARCH #2 NONCORROSIVE SASH CHAIN 6 IN. LONG.

Fig. 25. — Electrically lighted signal lamp.

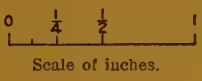
It is to be noted the electrically lighted lamp having a lens to deflect the light rays in approximate parallel lines is not provided with a reflector and only those rays of light are used which are projected directly from the light to the lens. The

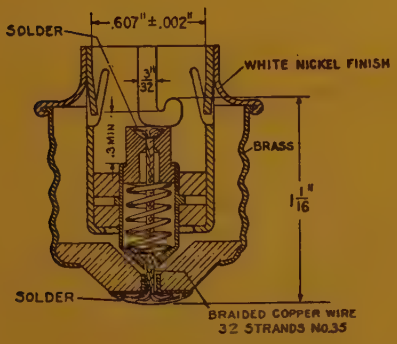
reason for this is that a reflector of design suitable for use with a lens has not as yet been placed on the market.

Electrically lighted lamps having a reflector and no lens are efficient and are in many cases bright enough to give a day



Note. — Allowable tolerance for light center and axial alignment of filament shall be plus or minus 1/32 inch.





Adapter.

Fig. 26. — Electric lamps and adapter.

indication, but must be used with a spectacle if more than one color is to be displayed, it being necessary for the lamp bulb to be lighted at all times to prevent light from an electric headlight or from the sun, that may shine into the reflector, being reflected back as a phantom light resulting in the display of a wrong indication.

Summary for discussion.

1° Is not the top draft method of ventilation the best for long time burning signal lamps?

2° Is not the light from a lamp equipped with long time burner as bright or brighter than if a flat wick burner is used?

3° With the long time burner using approximately but one sixth the oil required by the flat wick one day burner, is it not advisable, as a matter of economy and efficiency, the long time burner be used for signal lamps?

4° With practically all of the filament of the electric bulb coming within the focus of the lens is not electric lighting the most efficient means that has as yet been developed for lighting signal lamps?

5° Is it not best to use a lamp with electric bulb and lens, than an electric bulb with reflector which will make necessary the use of a mechanism to operate a spectacle with its several colored glasses to the proper position in front of lamp?

Automatic block signals.

The principles of signaling for the protection of trains running with the current of traffic on a double or three or more track road, have been given under « Signaling for a dense traffic », and there remains to be described under the heading of « Automatic block signals », the principles that apply where these signals are used for the protection of trains on single track. In the United States, of the 40 065 miles of road that are equipped with automatic block signals, 20 226 miles are single track. While the arrangement of the signals for single track blocking is practically the same as formerly, the controls provided are entirely different, in that instead of protection being provided for opposing movements only between adjacent signals, this is now extended to include the section of single track between two passing sidings, so that trains which are moving in opposite directions may normally meet only at passing sidings and the section between passing sidings may be used only by trains moving in one or the other direction.

On single track the signals must be so arranged that trains moving in opposite directions will each receive a « Stop » indication when they are braking distance apart, but with the controls formerly used trains were not held to meet at the passing point and if orders or instructions were overlooked and trains approached each other on the section between passing sidings, one or the other train had to back to the nearest passing point. This, when occurring, resulted in considerable delay and unnecessary expense of operation and to guard as far as practicable against this happening, the Absolute-Permissive-Block, or, as abbreviated, the A-P-B system of automatic block signaling for single track was developed.

In principle, the A-P-B system is arranged to permit the section of single track between passing sidings to be used at a given time only by trains running in but one direction, these trains being allowed to follow each other from one siding to the next, spaced and protected by the automatic block signals, the same as if running on a track with the current of traffic. While the section between passing sidings is occupied the route is held and may be used only for following movements. Trains desiring to move in the opposite direction are held at the siding at the far end of the section by a signal displaying a « Stop » indication. Immediately after the last train passes and the track between passing sidings is unoccupied, it is possible with the A-P-B system for a train to enter this single track section from either end, the first

train entering establishing the direction of authorized movement and the signal at the other end changing to display a « Stop » indication.

The A-P-B system of blocking has been found to be so efficient in its working and to so greatly increase the track capacity over that where manual blocking, or the older automatic single track system is in use that double tracking has in many cases been indefinitely postponed by the installation of the A-P-B system. It is, therefore, advisable before a second track is installed a careful study be made to determine if the track may be satisfactorily operated with A-P-B automatic signals and that it is economically desirable to build the additional track rather than to install the automatic signals.

While the A-P-B system control provides absolute blocking for opposing movements and permits trains to follow each other through the section between sidings under proper signal indications this control stops at the passing siding and for the section of main track paralleled by the siding the automatic signals governing in each direction are controlled by overlaps which give the desired protection and permits that freedom of movement which is required at passing points.

As it is necessary to arrange the signal controls to permit movements from a passing siding to the adjacent section of single track at any time the section is unoccupied, it follows that trains may leave each passing siding at exactly the same instant, with clear signal indications and enter the section of single track running in opposite directions. To insure protection against collision should this ever occur the section of single track must always be protected by not less than two signals that govern in opposite directions, these signals being located apart not less than the approximate braking distance and dividing the section into not less than two blocks for each direction. Although there is only the slightest chance, it may happen that two trains running in opposite directions will enter the single track section under clear signal indications at the same instant, « Stop » indications of the signals in the middle of the section must be displayed a sufficient distance apart to insure that trains so entering will be stopped before coming together. For safe working there must be not less than two blocks between passing sidings but the section may be divided into as many more blocks as its length makes desirable.

The location of automatic signals for protection of single track with different lenghts of track between sidings is shown in figure 27, it being noted that where there are more than two blocks between sidings the signals governing in opposite directions are placed at the same point, but on opposite sides of the track, this being a less expensive arrangement to install and maintain than where the signals are staggered along the track.

While the use of three signals for the protection of each end of a passing siding is shown because of the greater protection obtained, the arrangement generally used is to omit the signal for movements from siding and locate the two main track signals on the section of single track about 50 feet beyond the passing siding switch, as shown in the small diagram, figure 27.

Interlocking signals, from the fact they are manually operated are, after being used, generally changed to the position to display the proper indication for the passage of the next train, or are kept in the position indicating « Stop ». With automatic signals, owing to the difficulty experienced from ice and snow forming on the arm and interfering with the working of the signal, two different controls were

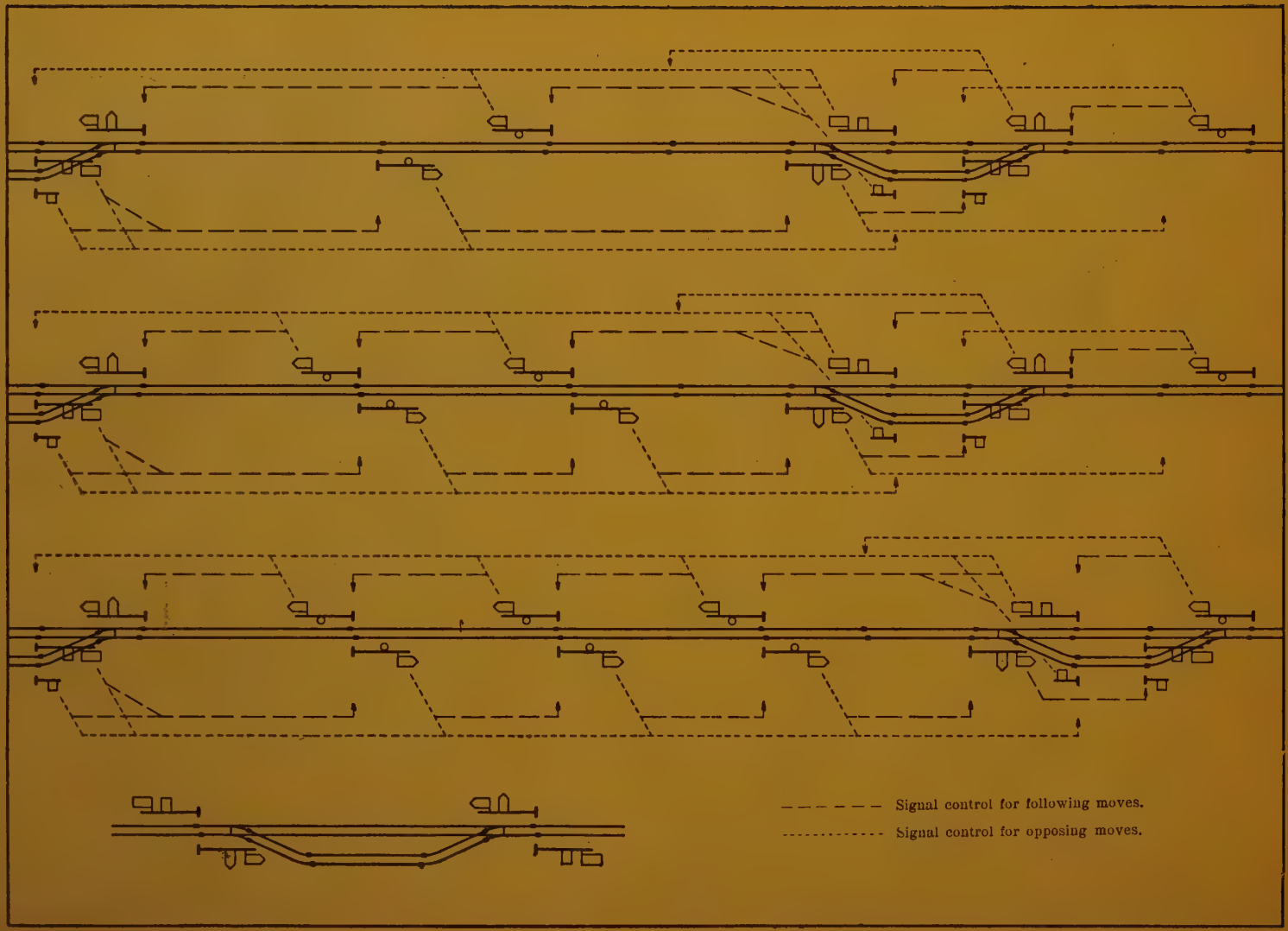


Fig. 27. — Typical locations and controls for signals, absolute-permissive-block system of signaling for single track

arranged. One where the semaphore arm remained normally in the clear position, unless occupying some other position to protect a train. The other where the arm occupied the position indicating « Stop » and was changed on the approach of a train to the position indicating « Proceed » only if it was proper to do so. With the normal clear system while the signal might improperly be held in the clear position from ice and snow collecting on the arm, an equally undesirable condition will result if certain parts of the normal stop system did not operate properly. The arguments in favor of either are not so conclusive as to result in the adoption of one or the other system as a standard, there being at the present time in the United States 55 880 miles of track with automatic signals arranged normally clear and 7 838 miles of track with the signals normally indicating « Stop ». With single track automatic signaling the normal clear arrangement is generally used as the circuits of the normal stop arrangement are so complicated little advantage is to be had from the use of this control.

With the simple overlap system of control for automatic signals on single track, square end arms are used and the signals display a « Stop » indication when the arm is in the horizontal position. It is evident this must be the indication displayed when it is remembered that the indication must be assumed to be displayed account of a train approaching from the opposite direction and under such circumstances it is necessary to send a man ahead to protect the train until a train is encountered moving in the opposite direction or a signal met with that is indicating « Proceed ». As a consequence, when a « Stop » indication is displayed account of a signal failing to operate, much time is lost owing to the slow speed at which a flagman is able to keep ahead of the train to the point where a signal indication is received for the train to proceed at speed.

With the A-P-B system restricting the use of the section of track between sidings to trains moving only in one direction, signals may be provided with the pointed end arm and diagonal lights and display the « Stop; then Proceed » indication, except for the signals located at the ends of the passing siding which must display a « Stop » indication to provide absolute blocking for opposing movements on the section of single track between sidings. As the signal at the end of the passing siding displays a « Stop » indication when the arms are in the horizontal position and the distance from one passing siding to the next is generally of such length a flagman may not proceed a train for the distance, it is practically necessary that a telephone be provided at the end of each passing siding by which communication may be had with the dispatcher should the signal indicate « Stop » when a train desired to proceed.

With the demonstrated greater reliability of the color light signal and the perfection to which the controls of the automatic signal have been developed, a number of installations of automatic signals have been made, and others are being arranged for, where these signals are used for the automatic protection of railroad grade crossings making it unnecessary to use an interlocking and employ signalmen to operate the levers of same. The arrangement of signals and the controls provided for a particular crossing are described in the June 1924 issue of *Bulletin of the International Railway Congress Association*, page 471. This installation is referred to for the purpose of calling attention to the desirability of and economy to be obtained by

the use of this arrangement of signals for places where the track layout is such that automatic signals may be used for the protection of trains moving over the crossing without first making the stop that is required by the Laws of Canada, and most of the States, unless interlocking signals are in use.

Summary for discussion.

1° If enginemen may safely be relied upon to obey indications of automatic signals of what need is there to provide additional or other controls than those required for the proper operation of the automatic signals?

2° Is not track circuit control more reliable and efficient than any other now in use?

3° Will not the A-P-B system of automatic block signaling provide for the running of a maximum number of trains on single track?

4° With the semaphore signal designed to operate properly under all conditions of weather is it not best that signals be normally clear and not install and have to maintain the additional line wires required for the normal stop arrangement?

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REPORT No. 1

(all countries, except America)

ON THE QUESTION OF STATISTICS (SUBJECT XI FOR DISCUSSION AT THE TENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION), (1)

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CONTENTS.

I. *Introductory note.* — II. *Particulars of statistics compiled and changes made in individual countries.* — III. *General remarks.* — IV. *Summary.* — V. *Appendices.*

I. — INTRODUCTORY NOTE.

The title chosen for this Report is « Development of railway statistics with the special view of economy in operation ». The Report therefore deals chiefly with those statistics which are used for the purpose of watching operating results, but other statistics have some bearing on the cost of operation, and a brief reference is made to the compilation of particulars which are not primarily operating statistics.

The chief function of a railway is to carry passengers and freight expeditiously and cheaply from one place to another. Efficiency and economy in the movement of traffic benefit both the railway and the trader, and increase the general prosperity of the country. Therefore the aim of all railway officers is to secure efficiency with economy, and this object can only be attained by a full knowledge of the relevant facts.

Statistics in one form or another have been used by railway officers all over the world ever since railways came into existence. The administrations in some countries commenced to compile and publish a full analysis of their working results at a much earlier date than others, but I think it is true to say that the general need for carefully compiled data became more keenly felt about the beginning of the present century owing to rising costs and the increasing complexity of railway business. The increases in expenses over which the railway administrations have little or no control, such as prices of materials, rates and taxes, etc., made it imperative that economies should be effected in other directions, and more attention has since been devoted to the compilation of information shewing the results of operation and the effect of changes in policy. In addition, the growth in traffic, and the increase in the size of the various systems owing to

(1) This question runs as follows : « Development of railway statistics with the special view of economy in operation. »

new construction and amalgamations, have emphasised the necessity for adequate statistics.

In order to ascertain the changes which have been made it was necessary to submit to the different administrations a series of questions. Information was obtained from forty-seven railways, and I desire to express my thanks to the Officers of those undertakings for the trouble taken by them in the matter. Certain administrations in order to indicate the developments which have taken place found it convenient to furnish copies of documents (*e. g.* Annual Reports, etc.) issued by them at various dates, and for this and other reasons I decided that the most practical way of dealing with the subject was to summarise in the body of the report the information received, and to print in the appendices particulars of the statistics now compiled by the railways in a few selected countries. A number of the documents sent to me are in languages with which unfortunately I am not personally acquainted, and if therefore I have not done justice to the progress made in any country, I trust that the members of the Congress will make allowance for my difficulties in this respect. The space devoted to individual countries has been determined chiefly by the changes which have been made since 1900, and by the amount of information which has been furnished by the respective administrations, or which I have been able to obtain from various documents.

II. — PARTICULARS OF STATISTICS COMPILED AND CHANGES MADE IN INDIVIDUAL COUNTRIES.

AUSTRALIA.

Acts of Parliament, relating to the construction, maintenance and management, of State Railways in Australia, which were passed in 1883, 1887 and 1888, provide, inter alia :

1° that in the first month in each quarter of every year the Commissioners shall report in writing to the Minister the state of the traffic returns, with the approximate cost and earnings per train-mile in respect of goods and passengers respectively carried during the quarter;

2° that the Commissioners shall also prepare an annual report, and

3° that both reports shall be laid before Parliament.

These Acts are still in force, but further requirements have been made in subsequent legislation. In addition the Census and Statistics Act of 1905 provides that the Commonwealth Statistician shall, subject to the regulations and directions of the Minister, collect annually statistics in relation to railways, and that all prescribed persons shall, to the best of their knowledge, supply the particulars required by the Statistician.

In 1909 the Statistician made a report to the Minister for Home affairs on the subject of « The desirability of improved statistics of Government Railways in Australia ». In this report Sir George H. Knibbs drew attention to the important differences which existed in the various States : *a*) in the particulars compiled; *b*) in the manner of compilation, and *c*) in the mode of presentation. He referred to the need for complete and uniform data in order to meet the requirements of the general public and of the Common-

wealth Government, and he emphasised the importance of statistics shewing the average receipt per passenger-mile for the different descriptions of passenger traffic, and per ton-mile for the various classes of commodities. With a view to effecting an improvement in the statistics he recommended that all the railways in the Commonwealth should compile and publish on the same basis the statistics mentioned in the report (*e. g.* mileage of lines, train-mileage, numbers of passengers, tonnage, and numbers of employees) and that they should classify their gross receipts and working expenses in an uniform manner. Sir George H. Knibbs recommended also that particulars of the number of passengers carried, the number of passenger-miles, and the gross amount received for passenger fares, should be given for each State under the classification of: *a*) suburban; *b*) extended suburban, and *c*) all other passengers, and that similarly for freight traffic particulars should be given of the revenue tons, revenue ton-miles, and gross receipts, separated according to commodities, under an uniform classification.

The report was considered by the Commissioners and General Managers of the Australian State Railways, and resolutions were passed agreeing to publish in the annual reports of the State Railway Departments uniform statistics regarding all matters referred to by the Statistician, with two exceptions, *viz.*:

1° Classification of tonnage carried and revenue derived therefrom;

2° Passenger and ton-miles.

With regard to 2°; it should be stated that passenger-miles have been compiled in Tasmania during the whole of the Commonwealth period(1). In New South Wales particulars are available to the 30 June 1910, for suburban and extended suburban traffic only; since that date all passenger traffic has been included. In South Australia statistics of passenger-miles are available since 1904, and in Victoria since 1918, but in Queensland and Western Australia this information has never been compiled. Particulars of ton-miles in New South Wales, South Australia and Tasmania, are available since 1901, in Western Australia for the years 1907 to 1912 and from 1918 onwards; and in Victoria from 1918; but the information is not compiled in Queensland. Commodity ton-miles are prepared only in New South Wales, Western Australia and Tasmania.

The principal annual figures relating to railways in the Commonwealth are published in the *Official Year Book*, and in the *Transport and Communication Bulletin*. In addition, a comprehensive summary of railway statistics is published quarterly. This publication is compiled under the instructions of the Australian Railways Commissioners by the Director of Railway Statistics in Sydney, New South Wales, and is circulated only to the Railway administrations of Australia. The pamphlet contains particulars relative to the railways of each State and also to the Commonwealth railway (Trans-Australian line).

The statistics compiled by the Railways of New South Wales appear to be the most detailed, and a list of the items of information relating to that State, which appears in the Quarterly Summary, is given in appendix B.

It is interesting to note that in 1919 a Committee of Officers appointed by the New South Wales administration enquired into the subject of the preparation of railway operating statistics. The whole system was remodelled and a Central

(1) The Commonwealth period commenced in 1901.

Statistical Bureau established, to which were transferred the officers who had previously prepared statistics under the supervision of the Chief Mechanical Engineer, the Chief Traffic Manager, and the Traffic Auditor. Many advantages in the way of supervision, uniformity of methods, preparation of locomotive and traffic figures in a neutral office, etc., have been obtained from the establishment of the Bureau, and the statistics have been extended considerably.

For the purpose of the domestic statistics, which are issued monthly to the Executive Officers, train and engine-miles and ton and vehicle-miles are taken out on a sectional basis for traffic in the up and down directions separately. A complete analysis of locomotive enginemen's time is made; every minute of the driver's time from signing on to signing off is accounted for under different headings, and worked up into percentages of the total time on duty. Train, engine, ton and vehicle-mile statistics are compiled from the combined driver's and guard's daily report sheets. Coal consumption is tabulated for each class of engine; ton-mileage is recorded for each class of engine (saturated and superheated engines separately) and traffic and locomotive operating costs are worked out on a train, engine and ton-mile basis. The mileage run by each engine is available also. Working expenses and earnings are shewn, and the cost of handling transhipment goods is recorded. All cases of irregular working are followed up by officers of the Bureau, and a *Review of the month's operations* is circulated with the statistics.

BELGIUM.

The statistics compiled on the Belgian State Railways have been extended considerably in recent years, and appendix C gives particulars of the information prepared for use at Headquarters and for Local Officers. The statistics which have been introduced, or extended, since the war are shewn separately from those instituted before the war. Monthly returns, and in some cases weekly returns, are now prepared in place of the old three-monthly statements, and this alteration enables such remedies as may be necessary to be applied quickly. Diagrams are largely used to provide a ready means of visualising the principal working results. Considerable attention is given to the use made of locomotive stock and enginemen, to the expenditure in wages, fuel and lubricants, and to the quantities of fuel and oil consumed. The particulars furnished in regard to fuel and oil consumption enable Headquarters to group the figures for all locomotives of any one type, or for all locomotives attached to any one shed, and thus to determine whether certain services have shewn excessive consumption; also to compare, in the case of a particular shed, the fuel consumed by each type of engine month by month. Each station is required to furnish particulars of the hours occupied in shunting service in relation to the vehicles shunted; this statement was introduced consequent upon the increase in the ratio of shunting-kilometres to train-kilometres.

In order to give effect to the proposal to deal with the Belgian State Railways on the basis of an industrial undertaking it is understood that other statistics will be required in addition to those set out in appendix C and that it will soon be possible to maintain a regular check on the paying load of trains. Statistics relating to each head of expenditure are also contemplated to facilitate a monthly check of the expenses.

CANADA.

Drastic changes were made in 1906 in the statistics furnished to the Government by the railways in the Dominion of Canada, and the Comptroller of Railway Statistics in his report for the year ended 30 June 1907, to the Deputy Minister of Railways stated :

This report is in many important respects different from those which have heretofore been presented. The schedules sent out to the various railways for statistical purposes, and upon which the accompanying tables are based, were much more elaborate than those which have been in use in Canada during the past thirty years. In all essential regards they are identical with the forms which had been adopted by the Interstate Commerce Commission at Washington. This change was made for a number of reasons. The old schedules had become unsuited to modern railway conditions. They failed to elicit many points of useful information. They did not, except in a limited way, permit of helpful comparisons with the railway statistics of other countries. In a word, they were obsolete.

It will not be alleged that these changes are in advance of existing needs. The problems of transportation rise above all others in importance, as bearing directly on the commercial life of the nation. All production, pastoral and industrial, with the labour involved, would practically cease if adequate marketing facilities were withdrawn; which is only another way of saying that the trade of the country is dependent upon the operation of railways. Scarcely less deplorable would be the position of the Dominion, having regard to the future, if railway construction and railway betterments should be indefinitely suspended. This will be conceded. And the problems of transportation in all their aspects can only be properly considered, and conditions measured, in the light of full and accurate statistical information. To meet this need is the purpose for which the new and comprehensive schedules above referred to have been given effect.

The principal changes made in 1906 included the compilation of passenger-miles, particulars of fuel consumption, numbers of employees and their earnings, capacity of cars, and greater details in regard to motive power and car supply. For some time prior to 1906 the railway companies had voluntarily compiled ton-miles for the use of their own officials, but from the 1 July of that year the compilation was made compulsory and the companies were required to furnish the information to the Government.

Further changes were made in 1915, chiefly with a view to maintaining comparable particulars with those compiled in the United States, and the information now prepared and published is in accordance with the schedules prescribed by the Interstate Commerce Commission of America. These Schedules will be fully dealt with, no doubt, by Colonel Loree, the American Reporter, but I think it is desirable that I should give some particulars of the domestic statistics compiled on the Canadian National Railways, especially as the information which is made available to their officers each month covers a wide field of railway operation. (See appendix D.) Considerations of space make it impossible to shew the exact manner in which the various statistics are placed in juxtaposition in order to present them in the form most useful to the Officers of the different departments. It will be understood that it is frequently necessary to shew the same items in two or more statements and I have, therefore, had to restrict the information given to a list

of the principal statistics. The majority of the statements which are issued shew particulars for each District separately, and each document is despatched from the Bureau of Statistics in Montreal immediately the information is available. Subsequently a comprehensive report reviewing the whole of the results for the month is prepared and issued by the Director of the Bureau.

CHINA.

The statistics relating to Chinese State Railways compiled prior to 1915 were, it is stated « Of a very summary character and gave little useful information ». They were therefore entirely revised and brought into conformity with the statistics of other countries as from the 1 January, 1915. The Chinese Administration realise that while statistics are essential to those responsible for the working of the railways they are necessary also for the purpose of enlisting public confidence and support, and in the preface to the annual report for 1916 the Standing Committee on the Unification of Railway Accounts and Statistics stated :

The railways in our country are still undeveloped. There are many lines yet to be built, and the building of those lines largely depends upon the co-operation of the public as well as of foreigners. The authorities should therefore keep the public informed as to the conditions and results of the railway operations with all sincerity, so that the co-operation of the public and foreigners may be counted upon... It seems fitting, therefore, that in these early reports, at least, considerable analysis should be made of bald results and that the considerations should be set forth by which such results are measured. Such analysis and considerations are offered with the object of educating the people to understand the importance of railway administration as well as its real conditions to the end that public opinion may be enlisted in a wise furtherance of railway policy.

CZECHOSLOVAKIA.

The statistics relating to the State Railways in Czechoslovakia had the same scope and the same fundamental basis in 1913 as in 1900. Even after Czechoslovakia was proclaimed a republic it did not seem opportune to modify the structure of these statistics, it being thought desirable to preserve the possibility of comparing the operations and the activity of the railway administration under quite different political and economic conditions. Minor modifications were required in the statistics relating to accidents and exceptional events in operation, and the freight statistics have recently been placed on an essentially improved footing.

DENMARK.

Comprehensive statistics of the results of working the railways in Denmark have been issued annually since the lines were opened for traffic, and the principal development in recent years has been the compilation of monthly statistics on the Danish State Railways for the use of the Chief administration and of local Executive Officers. The monthly statistics were commenced in April 1918, and they are printed and issued in the form of a pamphlet. Figures are shewn for each of the three districts into which the railways are divided.

DUTCH EAST INDIES.

Alterations have been made at various dates in the statistics compiled on the State Railways in the Dutch East Indies,

but I have no information shewing how the particulars which are now available compare with those of earlier years. Commencing with 1921 a separate volume of statistics has been published annually for the use of the officials and of persons interested in railways. Prior to 1921 statistics formed a minor part of the Annual Report.

FRANCE.

The statistics compiled by the State Railway in France have undergone no substantial modification since 1900 other than changes due to the purchase of the Western Railway on the 1 January 1909. In addition to the *Administration Report* and the *Statistical Documents* which are published annually, special statistics are compiled for the use of the local executive officers in regard to the volume of traffic conveyed, and for the purpose of providing a check on the working of the services. Among these special statistics may be mentioned in particular a statement of seasonal traffics, and a statement shewing the results of the application of new rates. The special statements are compiled daily, weekly, monthly or every 2 1/2 months, as is most suitable to the subject matter.

With regard to the concessionary companies; the compulsory statistics furnished to the Minister of Public Works have been curtailed since the war. The statistics compiled for their own use have remained approximately the same as they were in 1900, except that circumstances arising out of the war and the unification of railway rates have given rise to certain modifications, particularly in order to determine the causes of, and remedy for, any unsatisfactory turn-over of rolling stock, and to enable the effect on traffic and on revenue of new rates to be readily ascertained. Since 1 July 1920, the « Petite Vitesse Tarif » has been uniform for all the principal companies, and special importance has been attached to observing the results of the changes made. Attention may also be drawn to the use made by the French companies of statistics shewing the number of staff employed in ratio to the salaries and wages paid. These figures are specially mentioned by one Company as being valuable because they enable the cost per unit of labour to be compared, as between different periods on their own system, and as between their system and the systems of other companies.

Particulars of the statistics compiled on the Midi, Orléans, and Paris-Lyons-Mediterranean Railways are set out in appendix E.

GREAT BRITAIN.

Until as recently as 1913 the published statistics relating to Railways in Great Britain were confined to miles of line open (single and double track separately), number of passengers of each class, tons of general merchandise and minerals, passenger and goods train-mileage, and particulars of rolling stock. In 1906 the Board of Trade appointed a Committee « to consider and report what changes, if any, were desirable in the form and scope of the Accounts and statistical returns rendered by railway companies under the « Railway Regulation Acts », and the recommendations of the Committee — which were outlined by Sir William Acworth in the report submitted by him to the International Railway Congress at Berne in 1910 (1) — were embodied in the Railway Companies (Accounts and Returns) Act, 1911. This Act came into

(1) See *Bulletin of the Railway Congress*, January 1910, p. 3.

force on the 1 January 1913, and Section 1 states :

Every railway company shall annually prepare accounts and returns in accordance with the form set out in the First Schedule to this Act.

The schedule agrees in all respects with appendix I, which accompanied Sir William Acworth's report referred to above, and it provided, inter alia, for the number of steam engines of each wheel type, and the number of electric locomotives, rail motors, and electric motor vehicles to be shewn separately; for the seating accommodation of the different descriptions of passenger carriages to be given; for merchandise and mineral wagons to be classified according to their description and capacity; for the numbers of various descriptions of railway service vehicles to be recorded; for all duplicate stock to be included in the published returns; for particulars to be given of the number of locomotives, coaching vehicles, wagons, and service vehicles built on capital account, and the number renewed, repaired and under and awaiting repair; it provided also for engine-miles run, and passenger and freight traffic conveyed, to be shewn in much greater detail.

In addition to the statistics which the companies had to publish in accordance with the existing statutory obligations they, of course, kept other records for the use of their own administrations, but at the beginning of the present century very little statistical information was prepared regularly, and the decision as to what statistics should be compiled was left largely to the discretion of individual officers. For general supervision most of the companies relied upon «train-mile» figures — receipts per train-mile and expenses per train-mile — and very few continuous records of other locomotive or operating statistics were in existence. In 1902, however, one company commenced to compile ton-miles, wagon-miles, and other statistics, all of which formed connecting links in the chain of information available and provided a panoramic view of the situation so far as freight traffic was concerned; subsequently passenger-miles, coaching vehicle-miles, and seat-miles were added, but coaching vehicle-miles and seat-miles have not been compiled since the outbreak of war in 1914. Other companies, from time to time, increased their statistical data in the direction each thought most useful. After the termination of the war certain companies were arranging to make further additions to their statistics, but when the Government decided to appoint a Minister of Transport the companies realised that certain statistics would be required by him and they deemed it advisable to wait until these requirements were known.

Section 18 of the Ministry of Transport Act 1919 conferred wide powers temporarily upon the Minister of Transport in regard to statistics. This section reads as follows :

For the period of two years after the passing of this Act it shall be the duty of the owners of any railway, light railway, tramway, canal, inland navigation, dock, harbour, or pier undertaking... to furnish to the Minister in such manner and form as he may direct, such accounts, statistics and returns as he may require for the purpose of his powers and duties under this Act.

Immediately the Act was passed the Minister of Transport when framing his requirements took steps to obtain the assistance of the expert staffs of the railway companies in order that the information compiled should be useful not only to the Ministry, but also to the

companies in their own administration. Much thought was given to the matter by a special Committee appointed by the General Managers and after the list of statistics had been agreed upon, considerable time and labour were spent on the preparation of detailed instructions in order to secure uniformity in the compilation of the figures. The new arrangements came into force on the 1 January 1920, and in the following year they were made permanent by Section 77 (2) of the Railways Act, 1921, which reads as follows :

It shall be the duty of every railway company to compile and render to the Minister the Statistics and returns set out in the eighth schedule to this Act, sub-divided in the case of an amalgamated company in accordance with such operating areas as may be agreed between the Minister and the company, subject, nevertheless, to such variations of those statistics and returns as may from time to time be agreed between the Minister and the Railway Companies' Association.

Provided that the Minister may exempt any light railway company from the obligations imposed by this sub-section to such extent as he may think fit.

The eighth schedule referred to above is as follows :

Schedule of Statistics to be supplied by railway companies of Great Britain in addition to those furnished under Railway Companies (Accounts and Returns) Act, 1911.

1. Freight receipts, tons and ton-miles	Monthly.
2. Tons and receipts of selected commodities, conveyed at freight train rates	Monthly.
3. Commodity ton-miles	Monthly.
4. Passenger journeys and receipts	Monthly.
5. Passenger-miles	Periodically.
6 Quantities and receipts of parcels and miscellaneous traffic, conveyed at coaching train rates	Monthly.
7. Train and engine-miles and hours of company's engines over own and other systems	Monthly.
8. Train and engine-miles and hours over company's system by own and other companies' engines	Monthly.
9. Locomotives in use	Monthly.
10. Loaded and empty wagon-miles	Monthly.
11. Consumption of coal, electricity and oil by locomotives.	Monthly.
12. Construction and repair of rolling stock	Half-yearly.
13. Marshalling yard statistics	For a period of one month each half-year.
14. Census of staff shewing number of men in each grade at each rate of pay	Annually.
15. Tonnage conveyed on canals, separating principal commodities	Monthly.
16. Analysis of time spent by ships in port at railway-owned docks	Monthly.
17. Tonnage dealt with and cost of working at selected goods depots	For a period of one month each half year.

18. Tonnage carted and cost per ton at selected stations Motor cost to be distinguished from horse cost	For a period of one month each half year.
19. Capacity of wagon stock of various types	Annually.

All these statistics (except « Analysis of time spent in port at railway-owned docks ») are being furnished to and published by the Ministry of Transport, and in order that the members of the Congress may see precisely what information — in addition to that contained in the Annual Accounts of the Companies — is made available, I have set out in appendix F particulars of the statistics contained in the various tables which are published.

It will be seen from the foregoing paragraphs that the published figures have been made much more valuable in recent years. At the same time a considerable improvement has been effected in the domestic statistics compiled by the individual companies, their utility has been increased, and, partly as a result of the Acts of 1911, 1919 and 1921, a certain amount of standardisation has been effected. They still vary widely, however, both in form and scope in different parts of the country, and it is not possible within the compass of this report to do more than indicate briefly some of the particulars which are prepared for the purpose of tracing uneconomical working to its source, and for the use of local officers.

Most of the companies now compile returns shewing the average starting point wagon loads for general merchandise; coal, coke and patent fuel; and other minerals, separately, at every station on their system, and the particulars are summarised for each district or division. (One company compiles, in addition, occasional statements which shew the wagon loads obtained for individual commodities, *e. g.* bricks, grain, flour, iron and steel, timber, etc., etc.). Similarly, returns are prepared shewing the shunting engine-hours occupied and the number of wagons detached at marshalling yards and stations; the man-hours worked, wages paid, and tonnage handled, at the principal goods stations; and the cost of collection and delivery of goods train traffic at stations where this service is performed.

A few years ago a company which now forms part of one of the new groups inaugurated a scheme, known as the « Traffic analysis scheme », which shewed the flow of freight tonnage originating and terminating on that company's system. For the purpose of the scheme the railway was divided into a number of small areas, and the main object of the information compiled was to reveal any changes in the volume of traffic between the respective areas, so that such alterations could be made in the train services as might be necessary from time to time to ensure efficient and economical working. By this means through working to destination was arranged where the volume of traffic was sufficient to justify this being done, and staging from point to point was eliminated as much as possible. Subsequently it was found that a wagon basis was a more serviceable unit than tonnage and the scheme was altered accordingly. In connection with the scheme, particulars were obtained daily of the number of loaded and empty wagons : *a*) forwarded to and from each area; *b*) forwarded to foreign stations from each area, and *c*) received from foreign stations in each

area. This information was used to ascertain whether the traffic was being despatched by the proper services, to keep a check upon the distribution of empty wagons, to see whether more or less traffic was passing to and from other Companies' lines via the various junctions, and to keep a watch upon disadvantageous routing of traffic. These statistics, however, have now been discontinued as the development of an intensified system of train control enables the working to be more economically watched by other means.

One of the results of the establishment of train control has been that the company obtains many of the domestic statistics relating to part of its system through the medium of a Statistical Section attached to the Control Office. The loads of freight trains are watched by means of an analysis giving particulars of all trains passing a number of selected points; this analysis shews the haulage capacity of the engine, the actual gross tonnage hauled, and the spare capacity. Summaries are prepared giving the results for the whole of the freight trains daily, and also for each booked freight train day by day. By means of the latter summaries the Superintendent can keep any booked trains which are not loading satisfactorily under constant review with the object of making such alterations as may be desirable in train working. A separate statement is also prepared each day in regard to any specials which may be run, with a view to determining whether they were really necessary.

Until quite recently another company compiled particulars shewing the average number of wagons short of the maximum load for each freight train and totals for each division. The information was obtained from the Guards' Journals on which were shewn in three columns (according to their contents) the number of loaded wagons attached and detached, with a fourth column for empty wagons; the numbers thus shewn were equated either to coal or goods according to the description of train, and were compared with the maximum for the class of engine used. In substitution for these particulars a comprehensive return for each division is now compiled which shews :

Number of trains in division.
Actual train-miles in division.
Actual train engine-hours.
Regular booked train engine-hours in division.
Increase or decrease in regular booked train engine-hours in division.
Train-miles per train engine-hour.
Number of booked trains terminating in division.
Total minutes late at destination.
Average minutes late at destination.
Percentage of trains arriving to time.
— — 1 to 5 min. late.
— — 6 to 10 — —
— — 11 to 15 — —
— — over 15 — —
Wagon-miles, loaded.
— — empty.
Percentage of empty wagon-miles to total.
Wagon-miles per train-mile.
— — per engine-hour.
Number of specials run.
Net ton-miles.
Average train-load (tons).

The same company prepares statements shewing how the time of the freight train guards in each division has been occupied, and the summaries shew :

Number of guards employed.
Hours on duty.
Number of hours and percentage of time spent:
With trains;
Waiting;
Travelling;
Walking and other duties.

Another company prepares monthly a sectional wagon-mile return, which shews the loaded and empty wagon-miles, train-hours, train-shunting-hours, and train-miles, together with the average number of wagons per train, the average speed per hour, and the wagon-miles per train-engine-hour, for each of the chief train sections worked from each engine shed, and the total for each shed. This return enables the District Superintendent to locate readily the trains responsible for any low results in his district. A copy of the pro forma used is given in appendix G.

The introduction in Great Britain of « Common user » of goods wagons has materially altered the arrangements for the distribution of empty stock, and statistics are now used to a greater extent than formerly in connection with this service. The efficiency of distribution arrangements must depend on the accuracy of the information received from the stations, and about two years ago one of the new amalgamated companies instituted a statistical return which provides an effectual check on the station reports and is useful also for other purposes. The officials in charge of every station and siding furnish daily to the Central Wagon Control Office particulars of the number of wagons on hand at 9.0 a. m. and the number forwarded during the previous twenty-four hours. The Controller is thus able to check the number of wagons requisitioned with the number forwarded, and also to ascertain where slow working is taking place by comparing the number of wagons standing at stations and sidings with the number forwarded. Incidentally, the particulars rendered to the Central Control Office have made it possible to furnish to the traffic officers weekly a useful statement of the numbers of wagons forwarded from each district; the information is available three or four days after the end of the period to which it relates, and the particulars enable the traffic officers to form, more quickly than was previously possible, a reliable estimate of the state of trade, and to take promptly any action which may be necessary in connection therewith.

The domestic statistics which are compiled in connection with the working of passenger traffic are not so comprehensive as those relating to goods traffic. The loading of trains is watched by means of an occasional census of the number of passengers in each train at selected points, and particulars are available of the train-miles per train-hour and per engine-hour in each traffic Superintendent's division or district. Various means are adopted in different parts of the country for the purpose of localising unsatisfactory working. The practice followed by one company is as follows : « A perforated slip is attached to the guard's journal which, when completed, enables a summary to be compiled shewing :

Description of train.... from.... to....

Number of times run.

Total minutes lost in division :

By station work;
By waiting connections;
By engines;
By signals;
By engineering checks;
By exceptional causes.

Total minutes late start.
— — — entering division.
— — — leaving division.
— — — at destination.
Average minutes late at destination.

The slips are subsequently detached from the journals and after being sorted according to the description of train (*e. g.*

main line; cross country; branch; excursion; workmen, etc., etc.) the particulars shewn thereon are tabulated with the aid of calculating machines. Separate summaries are prepared for each Superintendent's division and for the whole line. Statements are also prepared shewing the percentage number of the various descriptions of train which arrived to time and similarly of those which were 1 to 5 minutes late, 6 to 10 minutes late, 11 to 15 minutes late, and over 15 minutes late.

The additional statistics compiled by the Chief Mechanical Engineers for the purpose of supervising the work of their Departments include : particulars of engines available for use, engines cleaned and cost per engine, engine-mileage, engine-hours, analysis of enginemen's wages, etc., for each district; miles run, and coal and oil consumed by individual engines; average ages of engines, coaching stock and wagons withdrawn from traffic; and particulars of the cost per train-mile, per engine-mile, and per engine-hour, of the various items of expenditure incurred by the locomotive department. Many of these returns have been elaborated in recent years.

It is also the practice in one part of the country to analyse in considerable detail for an occasional week the hours of engines engaged on freight working, and to shew the working from each engine shed and for each section of the line under the following headings :

Running :

a) with trains;
b) assisting and light.

Shunting :

a) on journeys;
b) at termini.

Signal detentions :

a) on journeys;
b) at termini.

At termini :

a) waiting for load;
b) balance of time.

Locomotive duties :

a) on journeys;
b) at termini.

Non-traffic time :

a) running to and from engine shed;
b) preparing and stabling engine.

GREECE.

There has not been any important change in the statistics compiled on the State railways in Greece during the last twenty years, but it is understood that it is the intention of the administration to put into force in the near future a more complete system of statistics than that now in operation.

HOLLAND.

Prior to 1917 the Dutch Railways were worked by four companies, each with its own system of statistics. The fusion of the companies led to some modification in the statistics and the compilation of certain data (including ton-kilometres) was discontinued. Particulars of the statistics which are compiled at the present time are set out in appendix H.

INDIA.

The statistics furnished to the Railway Board of the Government of India have always been voluminous, but for many years the general opinion held by Indian

Railway Officers was that much of the statistical information contained in the Annual Administration Report was of little use to railways for checking their own working. In 1921 the Acworth Committee referred to the necessity for a thorough over-hauling of the statistics published in the Annual Report and in 1922 a Committee consisting of Mr.W. H. Scott, Audit Department; and Major F. H. Budden, M. C., R. E., Traffic Department, was appointed to examine :

a) the form and scope of the present administrative statistics embodied in the Administration Report with a view to suggest reduction and improvement;

b) the form and scope of the revenue statistics and analysis of working prepared by individual lines with a view to suggest their improvement and restriction to what is found to be absolutely essential and useful for the internal control and economic working of the line;

c) generally the principles at present governing the preparation of statistical information on railways in India with a view to suggest improved methods of preparation with the primary objects of effecting economy in expenditure on statistical compilation;

d) the question of preparation of trade statistics at present prepared for government by railways with a view to avoid as far as possible special compilation by railway agency.

The report prepared by Messrs. Scott and Budden was issued in 1923. It deals exhaustively with the subject of railway statistics and is an exceedingly valuable document.

The introduction to the report states that the procedure adopted by the Committee had been « after finding out what statistics would be found useful by railways in checking the efficiency of their own working, to base their results on these figures ». Mention is made of the fact that they had « kept in mind the necessity of limiting statistics to those which are definitely required » and the opinion is also expressed that « as a general rule no statistics unnecessary to an agent should ordinarily find a place in the central administration preparations ».

The report deals with : 1° administrative statistics required for the Railway Board's use and for publication in the Administration Report; 2° operating and administrative statistics required for railway's own use; 3° the steps necessary to ensure that statistics are compiled and used in the right way; 4° methods of compilation; and 5° cost of compilation.

As regards administrative statistics required for the use of the Railway Board and for publication in the Administration Report; the principal changes recommended by the Committee and accepted by the Railway Board were :

a) The classification of railways under three classes for statistical purposes;

b) The introduction of monthly statistics in place of the yearly figures previously furnished, and

c) The division of important figures between main lines and branch lines.

With regard to *a*) ; fifteen railways each with gross earnings of over 50 lakhs of rupees (approximately £417 000) (1) in 1921-22 have been placed in class I; ten railways with earnings of under 50 lakhs but over 10 lakhs (approximately £83 000) (1), have been placed in class II and the remainder in class III.

The returns which are now furnished monthly to the Railway Board by class I railways give a truer indication than the old annual returns of the efficiency or otherwise of the undertakings. A summary of the information contained is set

(1) At 1 sh. 8 d. per rupee.

out in appendix I. Comparative particulars are shewn for the corresponding month in the preceding year, together with cumulative figures for each of the two years to date. For the purpose of ready reference each statistic is given a distinctive number. In the case of such items as train-miles, engine-hours, average speeds, wagon-miles, and average train-loads, the returns provide for separate figures being shewn for main lines (in one total) and branch lines (in one total).

Only one monthly return is required from other than class I railways. This return shews the number of passengers conveyed, passenger-miles, and corresponding receipts, and gives brief particulars in regard to train-miles, tonnage conveyed, ton-miles, freight earnings, working expenses, and coal consumed.

The railways are required also to furnish to the Board annual statements of the mileage of lines, rolling stock owned, constructed and maintained, and analyses of revenue and expenses. The Committee recommended that this information, together with that obtained from the monthly returns, should be embodied in the Annual Report of the Administration, and that the general sequence and form of the report should be on similar lines to the annual Railway Returns of Great Britain.

As regards operating and administrative statistics required for the railways' own use; the Committee found « that a general demand existed on all railways for more accurate and up-to-date figures », and after full investigation and discussion with the chief officers of the principal undertakings throughout India they were able to put forward proposals which met with general approval. The Committee recommended that statements should be compiled monthly for each district shewing all fundamental units such as train-miles, engine-miles, engine-hours, coaching vehicle miles, wagon miles, number of tons forwarded and carried, net ton-miles by selected commodities, gross ton-miles, tare ton-miles, capacity ton-miles, number of passengers forwarded and carried, passenger-miles, seat-miles, earnings and expenses, and the statistics which can be deduced from the fundamental units. The Committee laid stress upon the importance of a daily statement giving a brief summary of the results of working during the twenty-four hours ending midnight, and the exact position in regard to the conditions prevailing at important yards, etc., and they recommended that a document of this kind should be available for each District superintendent and Officers at Headquarters early on the following morning. In addition they set out particulars of other statistics which they considered essential for the use of local officers, and which they suggested should be compiled either daily, weekly, or monthly, as thought desirable. These proposals provided for returns giving much more detailed information of passenger train performance, goods train running and the loading of wagons, than are shewn in the monthly returns furnished to the Railway Board, and also for returns in regard to the working of goods sheds, passenger stations, and marshalling yards, the employment of engines and engine drivers, engine failures, working of engine sheds, and work done in locomotive, carriage and wagon repair shops.

IRELAND.

The changes in the statutory requirements in the Irish Free State and in Northern Ireland are identical with the alterations which have been made in Great Britain.

ITALY.

The operation of the Italian railways by the State began in 1905 and the statistics instituted at that time and included year by year in the published *Report on Working* and *Working statistics* remained unaltered until 1913.

During the war certain tables were discontinued and the *Report on Working* was simplified by certain omissions and by re-arrangement of material. The information which is published annually at the present time is however still voluminous, and in addition there is a considerable amount of statistical data prepared by the local executive officers which is not made public. Commencing with January 1924, a monthly bulletin, containing the more important information has been issued.

The State Railways are now actively engaged in revising all their working statistics with a view to their simplification and the addition thereto of new information. As far reaching changes may be introduced shortly it is perhaps unnecessary to deal exhaustively with the existing statistics.

JAPAN.

Many of the records relating to the railways in Japan were destroyed at Tokyo and Yokohama by the earthquake in September 1923. For this reason I have not been able to obtain particulars of the development of railway statistics which has taken place in Japan. The report of the Department of railways for the year 1920 shews, however, that the statistics compiled on the State lines, which embrace 75 % of the open mileage in that country, are very comprehensive and are in conformity with those prepared in the principal European countries. Separate figures are given for each of the six divisions into which the State system is divided. In addition to the annual statistics monthly figures are compiled for the use of the Administrative and Executive officers. Private railways are required to furnish certain information (*e. g.* train-miles, carriage-miles, wagon-miles, consumption of fuel, electric power, and lubricants, etc.) annually to the Department of Railways, and they are required to supply also the following particulars monthly : number of passengers conveyed, tonnage of goods conveyed, operating revenue, and the revenue for each station.

NEW ZEALAND.

No changes have been made during the past twenty-five years in the statistics compiled on the Government Railways in New Zealand, except in minor details, but the administration are arranging to commence to compile passenger-mile statistics at an early date.

NORWAY.

The annual railway statistics, which were established by the Central Administration of the State Railways in Norway, are published as part of the Norwegian Official Statistics. As from the 1 January 1922, a monthly statistical summary has also been compiled, but this is of a confidential character and is only circulated to the officers of the Central administration and to certain Institutes, etc.

POLAND.

The Ministry of Railways in Poland established railway statistics in that country in 1919. The Polish Railway system consists of nine « Directions »

each of which renders particulars of passengers, luggage, and merchandise traffic, and statistics of the mileage run by locomotives, carriages, and wagons.

PORTUGAL.

Particulars of the statistics compiled by the Portuguese Railway Company are set out in appendix J. The only changes made in recent years have been slight alterations in detail; in addition certain information which was formerly compiled for the use of local officers only, is now published with the other principal statistics.

ROUMANIA.

Up to 1914 the administration of the State railways in Roumania published statistics based on the data obtained for the use of the local operating officers, The summaries prepared for the use of the Central Administration contained comparative data over a series of years with regard to the working of the system in general, *i. e.* financial results, volume of transportation, in terms of passenger and ton-kilometres, and the revenue obtained, as well as data respecting the various descriptions of equipment, such as permanent way and rolling stock, and the condition and user thereof, the number of trains, train-engine and vehicle-kilometres, and census of staff. All these data were related to traffic units for the whole system and per unit of line open for traffic. The statistics for the use of the local operating officers contained detailed information of each branch; statistics relating to the commercial, operating, locomotive power, workshops, and maintenance of way sections, etc., were compiled in this way. After the war, in consequence of the disorganisation of the services, the statistics were compiled only in a summary form. As from the 1 January 1924, information has been obtained for the whole railway system of Greater Roumania, and the statistics have reverted to the pre-war position. They have also been arranged and co-ordinated with a view to bringing the particulars into conformity with those compiled in other countries.

SOUTH AFRICA.

The statistics published in the recent annual reports made by the General Manager of the Government Railways in South Africa to the Minister of Railways and Harbours differ to some extent from those shewn in the reports of administrations in other countries, inasmuch as they do not include ton-miles and the usual corollary statistics. On the other hand, they include : 1° the number of ordinary passenger bookings and the number of passenger journeys (including journeys of season-ticket-holders) on each of the various suburban services, and 2° particulars of the total tractive force, the average tractive force, and the average weight of locomotives in stock. As regards ton-miles; the compilation of the figures was suspended during the war. Experience, however, shewed that the administration were placed at some disadvantage without ton-mile figures and in 1923 (the latest year for which I have any information) they were compiled for at least two months.

The following paragraph, which has been extracted from the report of the General Manager for the year ended 31 March 1919, provides further evidence of the development of the practice of issuing information at more frequent intervals than was formerly the custom :

It is proposed to introduce a new

feature in the shape of periodical bulletins, by means of which information of public interest concerning Railway and Harbour operations will be disseminated as occasion arises, instead of being held over, as at present, for inclusion in the Annual Report.

For the information of the Chief Administrative and Executive Officers a statement is prepared monthly in respect of Branch Lines (lines which are regarded as developing lines); the statement gives particulars of the passenger and freight traffic conveyed, the train and engine-mileage run, the earnings and expenditure under various headings, and of the profit or loss after allowing for interest on capital.

SPAIN.

Very little alteration has been made since 1900 in the statistics which are compiled on the Northern Railway of Spain. In 1921 the particulars in regard to « Petite Vitesse » freight were amplified in order to bring the statistics into line with the new tariff arrangements.

SWEDEN.

The principal statistics of the Swedish Government Railways are to be found in the two printed publications, *viz :*

Monthly statistics of the Government railways (for internal use);
Annual Report of the Government railways.

Both publications serve the Chief Administration and the Executive Officers; a limited number of copies are distributed also to local officials with a view to creating interest in economy in operation. In addition, various statistical tables, relating to different departments and branches of the railway service, are prepared and issued, with a view to promoting efficiency in working. The railways are divided into five districts, and because they extend over a wide area and are composed of lines of a heterogeneous character as regards traffic density and economic conditions they are also sub-divided for statistical purposes into thirty line-areas.

In consequence of the need for quick and continuous information monthly statistics were introduced in 1913 and have been further developed. Particulars of the data which were made available in 1923 are set out in appendix K.

Changes in the Annual Report have been made from time to time with the object : 1° of extending and making the statistics more complete, and 2° of excluding details which are thought of insufficient importance. Since 1900 there has been a general improvement, and extensions have been made in nearly all branches of the statistics, and especially in connection with the more detailed particulars now compiled for different lines.

Particulars of the information contained in the statistical tables in the Annual Report are set out in appendix L. The figures in the Report are shewn for the Government Railways as a whole, and, in addition, in many of the tables, (*i. e.* those relating to train-kilometres, car-axle-kilometers, passenger-kilometres and ton-kilometres) separate figures are shewn for each district and each line-area.

With regard to the reasons which led to the amplification of the statistical information in the Annual Report it is stated :

The introduction of tables shewing the number of journeys and the numbers of tons of goods for each separate distance principally is of use for rate construction, and thus serves as an instrument

for greater efficiency for the purpose of raising the railways revenue and at the same time to keep in view the interests of the public. Besides this the different changes in the statistics can be said to correspond to the needs of the general officers for more and more complete statistical bases. The changes are the expressions of endeavours made gradually to improve the statistics with a view to finding a remedy for the business and its adaptation to new requirements.

Especially in connection with the detailed statistics of traffic density and the economic results of each part of the system, the need for such details is based upon the fundamental facts, mentioned before, that the Government railways are composed of very different parts, so that the data — especially the averages — which relate to the whole system are not sufficient to give a true view, unless at the same time an analysis is made of the different details which make the total; and in connection with the economic results of each line (group of lines) it is of great value to know, for instance, how great are the losses the Government railways have to bear for the public welfare through the low rates operative on the northern lines.

SWITZERLAND.

The only change in recent years in the operating statistics compiled for the use of the administration of the Federal Railways in Switzerland has been the addition of information relating to electric traction. Proposals for the extension of the operating statistics are under consideration.

III. — GENERAL REMARKS.

The problems which have to be dealt with by railway operating officers are much the same all over the world. The duties allotted to them necessitate arrangements being made for goods and passengers being economically dealt with at the termini, for the provision of suitable rolling stock and its proper utilisation, and for the expeditious and economical working of the traffic to its destination. It is universally recognised that full wagon loads and maximum train loads at economical speeds are of first importance from the standpoint of economy and efficiency in working freight traffic. A certain amount of deadweight must always be hauled and the greater the paying freight that is hauled with it the greater the proportion of profit. A permanent improvement in the wagon loads results in a reduction in the stock of wagons required, a reduction in the standage accommodation necessary at the termini, and a reduction in the cost of shunting. Maximum train loads reduce the train-mileage to a minimum, and a reduction in train-miles means that fewer engines are required to move a given quantity of traffic, with consequent savings in enginemen's wages and in capital invested in locomotives; a reduction in train-miles also has the advantage of reducing congestion, reducing delays, and of giving greater freedom of working. Moreover, as the capacity of a line is limited to the number of trains per day which can be worked over it, if train-miles are restricted as far as practicable, widenings of lines involving considerable capital outlay may be, and undoubtedly have been, ob-

viated. Other important factors are the elimination of delays en route, and the consumption of coal and other stores.

As the problems of management are everywhere very similar it is not surprising to find from an examination of the statistics published in various countries that as a result of developments in recent years there is now little difference in the fundamental or basic figures which are regarded as essential in connection with operation on the principal railway systems in Asia, Europe, and in the British Dominions and Colonies. The basic figures which are compiled by most of the undertakings, whether state owned or privately owned, include :

Mileage of lines.

Particulars of locomotives, carriages and wagons owned, available for use and in use.

Train and engine-miles.

Train and engine-hours.

Coaching vehicle and wagon-miles.

Freight tons.

Freight net ton-miles.

Freight train receipts.

Quantities of and receipts from certain selected traffics.

Passengers, number of.

Passenger-miles.

Passenger train receipts.

Fuel consumption and lubricating oil used.

Number of employees and particulars of earnings.

Expenditure under various headings.

In some countries it is the practice to compile also :

Axle-kilometres (*e. g.* Belgium, Czechoslovakia, Denmark, Dutch East Indies, France and Sweden) ;

Gross ton-kilometres, or gross ton-miles (*e. g.* Dutch East Indies, France, India and New South Wales).

Axle-kilometres are used in conjunction with ton-kilometres for the purpose of ascertaining the average load per axle; gross ton-kilometres are used to ascertain the gross train-load, to shew the gross ton-kilometres worked per engine hour, and the coal consumption in relation to the gross weight hauled.

Differences exist in the way in which the figures are segregated, and in the method of compilation.

Some of the variations in segregation are due to the different methods of charging for conveyance. In Great Britain freight traffic is classified for charging purposes under three main headings, *viz* : general merchandise; coal, coke and patent fuel; and other minerals (1). Tonnage and ton-miles are accordingly shewn under those headings, and for statistical purposes no distinction is made whether the traffic is carried by fast or slow trains, or in full wagon loads or in small lots. In many European countries, on the other hand, freight traffic is sub-divided into express freight, ordinary freight in small lots, and ordinary freight in full wagon-loads. In addition, separate particulars for coal traffic are in many cases compiled. Similarly in the case of train-miles, in Great-Britain freight trains of all descriptions are comprised in one total, while in some European countries it is a common practice to divide the mileage between express freight and ordinary freight trains. In the case of passenger trains, the number of journeys and total receipts are subdivided in Great-Britain under full fares, excursion and week-end, tourist, work-

(1) The term « other minerals » includes bricks, ironstone, iron ore, lime, limestone, pig iron, roadstone, sand, stone in the rough, and other heavy traffics.

men, and other descriptions of reduced fares, while in South Africa and in certain Australian States suburban traffic is shewn separately from other traffic. In some European countries, however, the distinction made is between ordinary trains and Fast or Express trains on which a special fare is payable, and coaching train-miles are separated in a corresponding manner. Where the latter practice is adopted the various figures relative to classes of traffic charged at different rates or fares can be isolated to some extent, and the loading of trains or vehicles and the receipts per ton-mile or passenger-mile for these sub-divisions separately observed. Some countries give more detailed information than others in regard to rolling stock owned, *e. g.* locomotives are subdivided in classes and figures of horse power or tractive effort are shewn; at least one country gives the weight of locomotives in place of tractive effort; in the case of vehicles, the number of axles is frequently given in addition to the number and capacity of vehicles.

Differences in the methods of compilation go far to impair the value of international comparisons. As an instance of the variations in practice it may be stated that in Great Britain the average haul of freight traffic for the whole country is ascertained by dividing the net ton-miles by the total tonnage originating, each ton being counted once only. In some parts of Europe, however, each ton is counted as many times as it is conveyed by different railways, the resultant average haul representing not the average for the country as a whole, but the average as between the several railways in the country. As a further illustration of the different practices which exist the following extract from the Australian Official Year Book for 1916 is quoted :

Ton-miles ..... In New South Wales the tonnage carried is exclusive of coal on which only shunting and haulage charges are collected, and the amount of earnings specified excludes terminals. In South Australia and Tasmania they include terminals, while in Western Australia they exclude wharfage and jetty dues, but include all other charges.

In making comparisons it is important also to remember that in Great Britain a ton consists of 2 240 lb. whereas in some countries it comprises only 2 000 lb.

As ton-miles form the basis of so many statistics it may be useful to make some reference to the mode of compilation and to the sources from which the figures are obtained. In some countries net ton-miles are based on the distance the traffic is conveyed, *e. g.* : Canada, Norway, Portugal, and Roumania; in other countries they are based on the distance charged for, *e. g.* Belgium and New Zealand; in New South Wales figures calculated on the distance travelled are used for statistics of operation, density, etc., and on the distance the traffic is charged for in connection with financial statistics; in France the practice seems to vary, but generally net ton-kilometres appear to be calculated on the distance charged for and gross ton-kilometres on the actual distance travelled by each wagon. Net ton-miles are usually compiled by multiplying the weight of the traffic as shewn on the invoices, or guards' reports, by either the chargeable or actual distance but different methods have been adopted in Great Brit-

ain and on the North Western Railway in India. The methods in these countries are as follows :

GREAT BRITAIN.

Net ton-miles are ascertained by multiplying the loaded wagon-miles for : *a*) General Merchandise and Live Stock; *b*) Coal, Coke and Patent Fuel, and *c*) Other Minerals, by the respective average wagon load for the three classes of traffic. For this purpose the average wagon loads are obtained by dividing the total forwarded and received tonnage by the total number of loaded wagons forwarded and received. In the case of the large companies, their systems have been divided into a number of small areas, and the average wagon loads in each area are applied to the relative loaded wagon-miles.

INDIA.

The method in operation on the North Western Railway is known as the « density » system. The initial tabulation consists of recording against the name of each station the traffic : *a*) received at the station; *b*) forwarded from the station, and *c*) passing the station. Having obtained these particulars the ton-miles are calculated by multiplying the density between successive stations by the distance between them and totalling the results. The following example for a railway with stations A, B, C, D, E, F, G, and H of which A, E, and H are junctions illustrates how the method works :

Miles. (1)	Station. (2)	Direction of traffic. (3)	Forwarded. (4)	Received. (5)	Passing. (6)	Ton-miles. (7)
		⋮	Tons.	Tons.	Tons.	
	Via A.	⋮	100	0		
...	A.	↓	60	0	...	...
5					160	800
	B.		70	5		
4					225	900
	C.		100	10		
3					315	945
	D.		30	5		
5					340	1 700
	Via E.		80	10		
...					...	...
	E.		120	30		
6					500	3 000
	F.		50	10		
3					540	1 620
	G.	⋮	20	80		
4					480	1 920
	Via H.	⋮	100	20		
...					...	...
	H.	↓	200	50		

Passenger-miles, train-miles, vehicle-miles, wagon-miles, engine-miles, etc., are all obtained similarly by this process on the North Western Railway, and figures are available not only for the system as a whole but also for any section of line (up and down separately).

The Report of the Committee which

was appointed in 1922 to examine the statistics of Indian Railways contains the following paragraph :

« It thus seems to the Committee, after having examined the principles at present governing the preparation of statistical information on railways, that the density system in use on the North Western Railway has a marked advantage over other methods, both in the reduction of labour it entails in the initial process of tabulation and the facility with which this tabulation yields the ordinarily required statistical factors for any portion of a railway, and they recommend in the interests of efficiency, economy and accuracy, that the question of the introduction of this system be further examined on other railways. »

Some of the concessionary companies in France do not compile unit-kilometres (ton and passenger) regularly month by month, but base the figures on tests made for limited periods. A somewhat similar practice is in operation on the Federal Railways in Switzerland.

Basic figures, if used separately, are of limited value only. For example, total train-miles merely shew whether more or less train-miles have been run, and total net ton-miles whether the volume of freight transportation has increased or not, but train-miles divided into ton-miles give the average train load and shew whether the train-miles run have increased in a greater or lesser degree than the volume of traffic. The general tendency now is to develop and make use of what may be termed « derivative » statistics (*i. e.* a combination of two or more basic figures) to a greater extent than was formerly the practice. These include :

Engine-miles and engine-hours in traffic per day per engine in use.

Train-miles per train-hour and per engine-hour.

Wagon-miles per train-hour per shunting-hour and per engine-hour.

Ton-miles per train-hour, per shunting-hour and per engine-hour.

Ton-miles per route-mile.

Average distances of freight and passenger traffic.

Average receipt per ton and per passenger.

Average receipt per ton-mile and per passenger-mile.

Number of vehicles per train.

Average load per vehicle.

Average load per train.

Per cent of loaded wagon-miles to total wagon-miles.

Lb. of coal consumed per engine-mile.

Pints of lubricating oil used per 100 engine-miles.

I do not think it is possible to classify in order of value the various statistics which are compiled. Every statistic which contributes towards economy and good working has its own individual value, but as railway operation depends upon so many factors I consider that the greatest value is obtained from statistics when used collectively rather than individually.

Statistics which may be regarded as two of the final tests of economy in operation, *viz*: cost per freight ton-mile and cost per passenger-mile, are rarely ascertained because of the difficulty of allocating the total expenditure of a railway between goods and passenger traffic. For the sake of uniformity and convenience the Canadian National Railways follow the rules prescribed by the Interstate Commerce Commission of the United States. In a few other countries the division is made on arbitrary bases. In Belgium passenger and freight expenses were divided before the war on the basis of engine and train-kilometres, and the Administration are at present seeking

another method of separation calculated to give a more exact result. The Committee appointed to examine Indian railway statistics, to which I have previously referred, found in the course of their enquiries that « it was the general opinion of all Agents that they would welcome some more scientific methods of dividing the expenditure between passenger and goods working », and the Committee recommended that the matter should be examined with this object in view.

The statistics which are published in the various countries are primarily for the use of those responsible for, or interested in, the general administration and policy of the railways. Statistics in greater detail are necessary for the use of officers of different rank. For example, a Yardmaster, or Local Agent, requires to know what is happening at the particular place for which he is responsible, whilst a District Superintendent, although interested in the average results for the whole system, is mainly concerned about the loads, speeds, train-hours, etc., on the different sections of line under his supervision, and the terminal costs at the various yards and goods depots in his district. Moreover, proper use of the average results for the whole system can never be made unless the domestic statistics available enable the district, yard, or depot where the working is not satisfactory, to be readily located. For these reasons domestic statistics are of great importance, and it is essential that not only should local and district officers be supplied promptly with full details of what is happening in the area under their control so that any necessary action can be taken without delay, but that in addition, the figures should be compiled generally in a manner which enables the information required by the Chief Administration to be built up from the particulars furnished to the District Officers. If the whole line figures are not obtained from this source, neither the cause of bad working, nor the locality in which it is occurring, can be easily ascertained when the general results are unsatisfactory.

So far as I have been able to ascertain domestic statistics differ widely in the matter of detail in different countries, and where the railways are privately owned there is no uniformity even among the undertakings in the same country. Reference has already been made under the heading of Great Britain to the diversity of practice which exists in this country, and under Australia to the particulars which are prepared in New South Wales. I am not in a position to place before the members of the Congress particulars of the domestic statistics compiled on all important railway undertakings in other countries, but a study of the information contained in part II of this Report and of the particulars in the various appendices will give some idea of the differences which exist.

Mention may be made of the following statistics, to which reference has not previously been made, and which either do not appear to be universally compiled, or, in the countries named, are subdivided in a special manner :

CANADA.

Potential ton-miles which are compiled in order to compare the actual average gross train-load with the estimated potential load.

Locomotive-miles equated to a common basis for the purpose of watching locomotive maintenance costs, etc.

Statistics of engine terminal performance at principal termini.

Statistics of number of days occupied by freight cars per average round trip,

sub-divided to shew how the time is spent.

Freight train-miles sub-divided under the headings of time (fast express), dead (ordinary through freight trains), and way (local pickup trains).

Lubricating oil consumption under the headings of car oil, valve oil, etc.

DENMARK AND SWEDEN.

Number of passengers; tons and ton-kilometres of express goods, ordinary goods, live stock, excess luggage, etc., at each distance, or in distance groups, *e. g.* 1-5 kilometres, 6-10 kilometres, 11-15 kilometres, etc.

FRANCE.

(Paris-Lyons-Mediterranean Railway.)

Number of passengers and corresponding receipts according to description of ticket.

Tonnage, *in distance groups*, of traffic conveyed at the rates and under the conditions of transport applicable to special « Petite Vitesse » tariffs.

Distribution of all descriptions of receipts between the lines forming the system.

Staff statistics, including :

1° Monthly numbers of the establishment, arranged according to grade and rate of pay;

2° Actual numbers of staff at end of each month, arranged according to grade and sex;

3° Distribution of staff at end of each year in various categories defined by Formula H. of the Railway Department of the Ministry of Public Works;

4° Monthly figures and corresponding graphs of :

a) Numbers employed in the theoretical establishment;

b) Numbers of established employees actually available;

c) Numbers of daily employees;

d) Units of work performed.

5° Various annual figures relating to merit marks gained by employees in various grades and at various scales of pay.

Train and engine-kilometres, vehicle-kilometres, gross and effective ton-kilometres, and average loads (gross and effective) of freight trains and wagons, for each line forming the system.

HOLLAND.

Train delays, analysed under each cause of delay, at stations and en route.

* * *

In order to ensure that statistics are compiled on uniform bases it is essential that clear instructions should be issued to those responsible for their preparation. More attention is given to this point than formerly, and the greater use which has been made of the figures in recent years has resulted indirectly in improvements being effected in the instructions and in more care being exercised in the compilation of the statistics.

A significant development of recent years, and one which indicates the increased importance attached to statistics, has been the appointment of Statistical Officers with separate staffs. Appointments of this kind have been made on the State Railways in Canada, New South Wales, and Western Australia, and on the railways in Great Britain, all of which are privately owned. The Committee for the revision of Statistics on Indian railways recommended that a special statistical officer should be appointed on each railway in that country.

There has been considerable improve-

ment in the way in which statistical information is presented to the public and to the officials of the undertakings. In some countries certain tables have been condensed because of the increased cost of printing and in order to provide space for more important information. In Norway, for example, the size of the annual report has been reduced by eliminating the less important tables; and in addition to those which have been definitely abolished, some are printed only once in five years and others have been abridged. The graphs also which were introduced in 1900-1901 appear now only once in five years. In another country, however, over 80 foolscap pages in a recent report were occupied by tables relating to the tonnage and receipts of traffics forwarded from and received at individual stations.

My report would be incomplete without some reference to education. The magnitude of existing railway undertakings, necessitates, in a greater measure than ever before, systematic study by members of the staff, and during recent years the railway companies in Great Britain have provided instruction in a variety of subjects through the universities and by classes arranged at convenient centres. The facilities for education in railway technical subjects are now much greater than they were a few years ago, and the importance of statistics has been recognised by the General Managers of the Railways in this country by the prominence given to the subject in the various syllabuses which have been drawn up. This importance is also appreciated by the Institute of Transport (Great Britain) and « Principles of Statistics, with special reference to transportation » is a compulsory subject in the Graduateship examination which must be passed by persons desirous of admission to the Institute as Graduates.

IV. — SUMMARY.

1. — There has been a considerable development of railway statistics during the past twenty-five years. The general tendency has been to extend the use of statistics to all branches of railway operation and to subject the working results to a much more detailed analysis and examination than was formerly the practice.

2. — As a result of developments in recent years there is now little difference in the fundamental or basic figures which are regarded as essential in connection with railway operation and which are compiled on the principal undertakings in the various countries for the use of those responsible for, or interested in, the general administration and policy of the railways.

3. — Differences exist in the segregation of the figures and in the methods of compilation.

4. — Differences in the methods of compilation impair the value of international comparisons, except where the variations in methods can be measured and allowed for.

5. — Domestic statistics, as distinct from the figures which are published, are of primary importance :

a) To assist local officers to secure

efficiency and economy in the working of the area under their control;

b) To enable the chief administration to see the results of the efforts of local officers, and

c) To enable the locality where the working is not satisfactory to be readily discovered when the average results for the whole system shew a decline.

6. — Domestic statistics differ widely in different countries, and where the railways are privately owned there is no uniformity even among the undertakings in the same country.

7. — Variations in domestic statistics may be immaterial if the statements which are prepared achieve the same results. It is important, however, that the figures should be compiled generally in a manner which enables the information required by the chief administration to be built up from the particulars furnished to district officers. If this is not done, neither the cause of bad working nor the locality in which it is occurring, can be easily ascertained when the general results are unsatisfactory.

8. — It is customary now :

a) to develop and make use of « derivative » statistics (*i. e.* a combination of two or more basic figures);

b) to compile and issue statistics monthly intead of quarterly or annually, and

c) to separate the figures into districts, to a much greater extent than formerly.

9. — More attention has been given in recent years to the preparation of clear and definite intructions for the guidance of those responsible for the compilation of statistics, and greater accuracy and uniformity have been secured thereby.

10. — The use of calculating machines has resulted not only in greater rapidity in compiling statistics, but also in a reduction in the number of staff employed on this work.

11. — The prompt issue of statistics is important, particularly in the case of monthly figures which are prepared for executive officers. It is the practice in some countries to issue a statement relative to each phase of working immediately the figures become available, while in other countries the whole of the figures for the month are issued in book or pamphlet form.

12. — The manner in which the figures are presented is also important in order that the salient features can be readily observed.

13. — A development in recent years has been the appointment on many railway systems of Statistical Officers with separate staffs. These appointments have had the effect of eliminating overlapping in the compilation of statistical data, of securing greater accuracy and uniformity and of enabling better use to be made of the information available.

14. — The importance of educating the staff in regard to statistics — the methods of compilation, and the use which can be made of the various figures separately and collectively — is now recognised, and in Great Britain the subject is included in the various syllabuses of classes and lectures arranged for the purpose of providing education in railway technical subjects.

APPENDICES.

Appendix A.

Detailed list of questions relating to question XI.

LIST OF QUESTIONS.

1. — Give particulars of the statistics compiled on your Railway in 1900, 1913, and at the present time :

a) for the Chief Administration;

b) for the local use of the Executive Officers.

2. — Indicate briefly the reasons which led to the additions to, or modifications in, the information furnished at the several dates.

3. — Are the statistics, which are furnished to the Chief Administration for the whole line, built up from the statistics prepared for the local use of the Executive Officers ? If not, in the event of the figures revealing unsatisfactory results, how are the causes localised ?

4. — State which of the statistics, or combination of statistics, you consider the most valuable for the purpose of securing economy and efficiency in operation.

5. — If your Railway is owned by a Company and not by the State, is the compilation of any of the statistics compulsory ? If so, indicate which statistics are compiled to meet the requirements of the Government.

6. — Are the statistics published, or are they circulated to the Officials of your Railway only ?

7. — Are the statistics issued four-weekly, monthly, quarterly, or annually ?

8. — How long after the end of the period to which they relate are the statistics made available ?

9. — If ton-miles (or ton-kilometres) are compiled :

a) from what source is the information obtained ?

b) are the figures based on the distance the traffic is charged, or on the distance over which it is worked ?

10. — Do you apportion your expenditure approximately between passenger and goods services, and if so, how is the division made ?

11. — If expenditure is not apportioned, is any « traffic unit » figure developed, *i. e.*, a statistic which can be used for analysing and testing railway operations as a whole without the separation of passenger and freight figures ? If so, give details, and in the event of the « traffic unit » consisting of a combination of ton-miles and passenger-miles state the basis by which passenger-miles are restated in terms of ton-miles, or *vice versa*.

Appendix B.

AUSTRALIA : NEW SOUTH WALES.

Information recorded in quarterly summary.

COACHING TRAFFIC.

Passenger journeys :
- First class ;
- Second class ;
- Workmen's weekly tickets ;
- Season tickets under classes.

Passenger miles : country and suburban traffic separately.

Average miles each passenger was carried.

Average number of passengers per car and train mile.

Average number of cars per train.

Average number of journeys per head of population.
Passenger ton-miles : gross.
Average train load : gross.
Other coaching traffic : details.
Earnings in total, per train-mile, per mile of line open, and per passenger journey.

Goods traffic.

Tonnage carried under chief commodity headings.
Earnings in total; per train-mile; per mile of line open; per ton; and per ton-mile.
Net ton-miles.
Gross ton-miles.
Average haul-miles.
— wagon load.
— truck capacity.
— train load : gross.
— — — net.
Average net ton-miles per goods wagon (« in service » and total stock separately) per day of twenty-four hours.
Average number of vehicles per goods train :
Loaded;
Empty.

Working expenses.

Expenditure in total; per mile of line open; per train-mile; and per 1 000. gross ton-miles, under each of the following sub-headings :
Maintenance of way and works;
— of rolling stock;
Locomotive power;
Lubrication;
Transportation and traffic branches;
Miscellaneous.

Train mileage.

Passenger :
Country;
Suburban.
Mixed.
Goods.
Departmental.
Shunting.

ENGINE MILES.

Car and wagon-miles.

Passenger stock :
Country;
Suburban.
Merchandise stock :
Loaded;
Empty.
Service stock :
Coaching;
Goods.
Average mileage run per vehicle per day of twenty-four hours :
Passenger vehicles (in traffic);
— — (total stock);
Merchandise wagons (in traffic);
— — (total stock).

Locomotive drivers' operating statistics.

Total hours drivers on duty.
Percentage of actual, running time by drivers.
Percentage of drivers hours engaged in Departmental services.
Percentage of standing time :
Traffic causes;
Locomotive causes.
Miles run per driver's hour in traffic service (« en route ») :
Passenger;
Mixed;
Goods;
All trains.
Engine-miles per hour for all time drivers on duty.
Engine-miles per hour in traffic service.
Ton-miles per driver's hour in traffic service.
Ton-miles per hour drivers are on duty.

Locomotive fuel and oil consumption.

Consumption of :
Cylinder oil : ... gallons.
Engine bearing oil : ... gallons.
Car and wagon oil : ... gallons
Coal : tons.
Total cost and average cost per gallon of oil under each of the headings shewn above.
Total cost and average cost per ton of coal.
Engine-miles and ton-miles per gallon of oil.

Lb. of coal consumed per mile.
Cost of oil and coal per 10 000 gross ton-miles.
Ton-miles per ton of coal.
Consumption of coal (cwts.) per 10 000 ton-miles.

STAFF AND WAGES.

Total wages and salaries paid on :
Working expenses;
Capital and other charges.

Number of wages and salaried staff on :
Working expenses;
Capital and other charges.

Average rate of pay per annum :
Salaried staff;
Wages staff.

Average number of wages and salaried staff on working expenses per 1 000 engine miles.

Appendix C.

BELGIAN STATE RAILWAYS.

I. — Statistics instituted before the War.

DOMESTIC STATISTICS
FOR USE AT HEADQUARTERS.

Issued annually :

Length of line, level crossings, and private sidings.

Number of trains and train-mileage, according to service.

Financial results of operation and working coefficient.

Census of staff (officers, clerks and workmen); Stock of locomotives, tenders, carriages and wagons; and number of stations.

Volume of passenger traffic and receipts. Statistics of passenger traffic, based on the actual numbers of ordinary and season tickets issued. The number of journeys by season ticket holders is based on an average user ascertained by experience for each class of periodical ticket.

Average receipt per passenger journey.

Issued monthly :

Volume of certain commodities conveyed in full loads : 1° by local and international services, and 2° by all mixed services, forwarded and received separately, and 3° total.

Note. — « Mixed » services are those in which traffic passes over the lines of the Belgian State Railways and of other Belgian Railways, *e. g.* « Nord-Belge ».

Volume of international service heavy freight traffic forwarded and received by State railway stations.

Volume of freight traffic in transit through Belgium.

Volume of freight traffic in transit through Belgium over the State Railways.

Volume of traffic : horses, cattle, vehicles running on their own wheels, etc. : 1° by interior services, and 2° mixed services and international services, forwarded and received separately, and 3° total.

Volume of traffic in tons of heavy commodities conveyed during the period by the Belgian State Railways.

Statement of tonnage and ton-kilometres of heavy freight charged at tariff 3 and conveyed in full loads. Down to 1922 this item was compiled annually. In the course of 1922 an experimental modification was made in the method of compiling this information, and commencing in 1923 the new system was confirmed and definitely adopted. It consists in the introduction of special forms, which allow a monthly instead of annual consideration of :

1° The tonnage of each commodity dealt with;

2° The ton-kilometres of each commodity dealt with;

3° The average train load.

The object of this modification was to secure the most complete information possible as to the volume of freight passing, and from such particulars to make comparisons of the fluctuations in traffic and deduce what tendencies should be followed in fixing tariffs.

DOMESTIC STATISTICS FOR USE AT HEADQUARTERS AND BY LOCAL OFFICERS.

Issued monthly :

Locomotives in traffic and fuel and oil consumption. In 1900 and 1913 each individual locomotive depot compiled a three-monthly statement shewing the distance run and fuel consumed by each locomotive, with totals for each type. At the Divisional Office, which controls a certain number of depots, totals were compiled on identical pro forma per engine house and per type. Lastly, at Headquarters, the particulars furnished by the Divisions were comprised in a grand total under types, from which averages per type were deduced. Each year there was published with the annual report on the Locomotive Running Department a statement giving the total consumption and distance run by each type, and the resultant averages. These statistics are still compiled, but the Divisional Offices and the Locomotive depots compile monthly figures instead of three-monthly.

Distances run by foreign locomotives over Belgian State Railways, and by Belgian State locomotives over foreign systems. These figures were and are still compiled on a Form adapted for the insertion month by month of the distances run over each section of line. Each type of train (passenger, freight, etc.) is shewn separately.

Issued annually :

Description, etc., of locomotives (power in horse power, weight, number of axles).

Number of and receipts from Periodical Tickets available for five and fifteen days.

Receipts from all descriptions of Periodical Tickets

Issued weekly :

Comparative table shewing number of goods wagons supplied during each week in the year.

Graph shewing number of wagons in stock, average number demanded and supplied, and number supplied less than demanded, per working day during the acutest period of heavy traffic (mid-October to mid-November).

II. — Statistics instituted since the War.

DOMESTIC STATISTICS FOR USE AT HEADQUARTERS.

Issued monthly :

Comparative table of traffic receipts and consumption and cost of fuel on Belgian State Railways; ratio between consumption and cost of fuel and traffic receipts; and average price of coal and « briquettes ». Compiled to ascertain the percentage of expenditure on fuel in relation to traffic receipts.

INTERNATIONAL STATISTICS FOR USE AT HEADQUARTERS.

Issued annually :

In order to compare the working results of the Belgian State Railways with those of foreign countries, loose-leaf forms have been introduced shewing over a series of years the particulars enumerated below. It should be appreciated that the comparison is made with the railways with which the Belgian State Railways are most closely connected.

Length of line.

Original capital cost.

Cost per kilometre.

Return on capital.
Stock of locomotives.
Stock of locomotives per kilometre of line operated.
Stock of passenger carriages.
Stock of passenger carriages per kilometre of line operated.
Stock of wagons.
Stock of wagons per kilometre of line operated.
Annual number of trains.
Total train-kilometres.
Average distance per train.
Total engine-kilometres.
Average number of kilometres run per engine.
Total gross receipts.
Average gross receipts per kilometre of line operated.
Total working expenses.
Average working expenses per kilometre of line operated.
Total net receipts.
Average net receipts per kilometre of line operated.
Coefficient of working.
Total passenger receipts.
Number of passenger journeys.
Average distance per passenger journey.
Average receipt per passenger journey.
Average receipt per passenger-kilometre.
Total of heavy freight.
Number of tons of heavy freight.
Average haul of heavy freight.
Average receipt per ton of heavy freight.
Average receipt per ton-kilometre of heavy freight.
Census of staff.
Number of persons killed in accidents on the railway.
Number of passengers carried per passenger killed.
Number of passenger-kilometres per passenger killed.
Number of passenger-train-kilometres per passenger killed.
Number of train-kilometres (all services) per employee killed.
Number of employees per employee killed.
Stores supplied.
Stores supplied per kilometre of line operated.
Number of passenger-kilometres.
Number of ton-kilometres of heavy traffic.

DIAGRAMS FOR USE AT HEADQUARTERS.

The diagrams enumerated below are intended to provide a means of rapidly and easily following and comparing the principal working results.

Issued monthly (M) *or weekly* (W).

W. Consumption of fuel and lubricants per engine-kilometre.

W. Cost of fuel per engine-kilometre.

W. Percentage of small coal.

M. Average ash content.

M. Price of coal, and briquettes for locomotives.

M. Ratio of cost of fuel to total traffic receipts of Belgian State Railways.

W. Comparative wholesale cost of English and Belgian coal.

M. Locomotive fuel consumption in tons per million francs of traffic receipts.

M. Expenditure per train-kilometre :
1° Passenger.
2° Freight :
a) Fuel ;
b) Wages of engine crew ;
c) Lubricants.

M. Percentage of passenger and freight services respectively of :
a) Locomotives in use ;
b) Shunting kilometres ;
c) Locomotives not available for service ;
d) Train-kilometres, with more than one locomotive ;
e) Empty-kilometres (? Light).

M. Approximate traffic receipts of Belgian State Railways.

M. Average traffic receipts of Belgian State Railways :
  1° Per passenger-train-kilometre;
  2° Per freight-train-kilometre.

M. Kilometres on passenger and freight service respectively of :
  1° Locomotives with trains ;
  2° Trains;
  3° Shunting at stations (manœuvres de gare);
  4° Trains with more than one locomotive;
  5° Shunting of trains (manœuvres de trains);
  6° Light.

M. Average daily kilometrage worked on passenger and freight services respectively :
  1° Per locomotive;
  2° Per driver.

W. Ratio of light engine-kilometres to train-kilometres.

W. Total and average per day of train-kilometres on passenger and freight services.

W. Average daily train-kilometres :
  a) Per train-engine driver;
  b) Per driver (all services).

W. Number of wagons loaded.

M. Receipts from traffic forwarded or received on the following services : with Nord-Belge, Prince-Henri, Alsace-Lorraine, Dutch State, Guillaume-Luxembourg, the Saar, Prussian-Hessian, East German, French, Franco-Belge-North, Franco-Belge-East, German-North-French, and Franco-Belge-Dutch Railways.

M. Marshalling expenses (engine-men, guards, shunters, etc.) per 1 000 engine-kilometres.

M. Ratio of marshalling expenses to traffic receipts.

M/W. Wholesale prices :
  M. Steel rails.
  M. Steel plates (Thomas).
  M. Steel bars.
  M. Pig-iron :
    Thomas ;
    Luxemburg.
  M. Homogeneous iron plates.
  W. Non-ferrous metals :
    Copper ;
    Zinc ;
    Tin ;
    Lead.
  W. Cotton.
  W. Turpentine.
  W. Canvas.
  W. Petrol.
  W. Oils :
    Linseed ;
    Colza ;
    Petrol;
    Benzine.
  W. Rubber.
  W. Wool.

The diagrams of wholesale prices are designed to shew :

1° Whether the prices asked by the contractors are in relation to the wholesale prices of these commodities and are consequently acceptable;

2° The most favourable time at which to place orders.

Domestic statistics for use at Headquarters and by Local Officers.

Issued monthly :

Monthly statement of locomotives in use, number of enginemen on duty and loco-running department expenses per train-kilometre.

By means of statements compiled each month by the locomotive depots each district makes a summary which is forwarded to

Headquarters, where in turn the figures furnished by the districts are collated in a General Statement.

This statement is sent to all districts and Chief Officers, and shews, under passenger and freight services separately, what use has been made of the locomotive stock and enginemen, and the expenditure in wages, fuel and lubricants. The fluctuation in these can thus be followed from month to month.

The Monthly Statements are more accurate than the Weekly Statements. They reach Headquarters a fortnight after the end of the month. The General Statement is a most interesting document, which permits month by month of steps being taken at once to correct results which shew unsatisfactory tendencies (*e. g.* too many locomotives stopped for repairs, too many light kilometres, increased brakesmen's expenditure, etc.).

Statement shewing cost of shunting :

Each locomotive depot compiles engine-hours on shunting service at each station, coaching and freight. The district office groups the depot particulars, and Headquarters summarises the data for the whole system.

The Statement shews, by the variation in engine-hours, whether the use of shunting-engine power has been excessive.

It was instituted because it was observed that the ratio of shunting-kilometres to train-kilometres was rising, and it was desired to ascertain where the increase arose.

The Statement also aims, by shewing shunting-engine-hours in relation to wagons shunted, to compare the output of various stations.

Statement of fuel and oil consumption per engine-type and per engine-shed :

The Depot Statements giving details of the work and fuel consumption of the locomotives only reach Headquarters about two months after the period to which they refer. Short extracts shewing total kilometres run, total fuel consumption and average fuel consumption per locomotive and per type, are sent in advance within fifteen days by the Depots to Headquarters direct. The official in charge of the Depot has to send an Inspector to travel on any locomotive whose consumption is excessive. These extracts enable Headquarters to group the consumption figures for all locomotives of any one type or for all locomotives attached to any one shed, and thus to determine whether certain services have shewn excessive consumption; also to compare, in the case of a given Depot in different months, the fuel consumed by each type of engine, which enables a check to be kept whether consumption is being reduced or is tending to rise. It is a simple matter if the consumption at a given shed is increasing to pick out the engine types which have had a preponderating effect. Enquiry at the depot helps to determine the reasons and often enables the necessary remedial measures to be enforced at once.

Classification of engine depots in order of merit, according to percentage of economy or excess in fuel and oil consumption based on a standard allowance :

Tables shewing comparative results for all locomotive depots, which are thereby enabled to compare their figures, with the result that their efforts are stimulated.

Statement shewing number of drivers who have been awarded the economy bonus :

The table shews the maximum and average bonus paid at each depot. It is thus possible to see the total amount paid in bonus, and, if necessary, to examine the reasons for any exceptionally high bonus which may have been paid, and adjust the basis.

Issued weekly :

Statement of locomotives in use and their consumption of fuel and lubricants :

The locomotive depots record daily details of the kilometres run and fuel consumed by all engines in service, and send weekly to the District Locomotive Superintendent a summary of the data for the week.

The District Officers group the particulars of the depots under their control and send the summary to Headquarters, where a general weekly statement is compiled for the whole system. This statement is compographed and sent to the various districts and Chief Officers. By its means it is possible to follow regularly the consumption of fuel and lubricants the proportion of briquettes and small coal used, the average daily distance run, the percentage of light running, and also to determine quickly the results of any defective working.

The Statements are available a week after the period to which they refer and enable a remedy to be applied quickly, either for poor running results or for excess in consumption.

It will be readily understood that these statistics are far more effective than the old three-monthly statements.

Appendix D.

List of principal statistics compiled monthly for the officers of the Canadian National Railways.

OPERATING REVENUES.

Freight	Totals, and averages per mile of road operated and per train-mile.
Passenger	
Mail	
Express	
All other	

OPERATING EXPENSES.

Maintenance of way and structures . . .	Totals, and averages per mile of road operated and per train-mile.
Maintenance of equipment	
Traffic	
Transportation . . .	
Miscellaneous	
General	

NET EARNINGS. Ditto.

OPERATING RATIO.

LOCOMOTIVE MILEAGE.

Train	Freight and passenger separately, and in the case of train-miles separate figures are shewn also for « mixed » and « special ». Freight train-miles are sub-divided into three classes, *viz.* : time, dead, and way (or local) (*a*).
Train switching.	
Yard switching.	
Light	
Helper	
Work	

20 °/₀ capacity locomotive mileage (*b*).

LOCOMOTIVES.

Average number on line daily :

Serviceable :	Separate figures are shewn for freight; passenger; mixed and special; yard and work.
Assigned	
Stored	
Unserviceable :	
Per cent unserviceable	

Average daily mileage per serviceable locomotive :
- Freight;
- Passenger.

Number of main shop repairs completed (*c*).
Number awaiting main shop repairs, on first and last day of month (*c*).
Number under main shop repairs, on first and last day of month (*c*).
Percentage awaiting and under main shop repairs at close of month (*c*).

LOCOMOTIVE MAINTENANCE COSTS.

Running repairs :
- Labour. . . . . }
- Materials. . . . . } Averages per locomotive mile and per 20 % capacity mile.

Shop repairs :
- Labour. . . . . }
- Materials. . . . . }

COAL CONSUMPTION.

Per locomotive-mile :
- Freight . . . . . lb.
- Passenger. . . . . lb.

Per 1 000 gross ton-miles :
- Freight . . . . . lb.

Per passenger train car-mile :
- Passenger. . . . . lb.

Per yard locomotive-mile . . . . . lb.

LUBRICATING OIL CONSUMPTION.

Locomotive-miles per pint :
- Car oil;
- Valve oil;
- D. J. Compound;
- R. C. Grease.

20 % capacity-miles per pint :
- Car oil;
- Valve oil;
- D. J. Compound;
- R. C. Grease.

ENGINE TERMINAL PERFORMANCE (*principal termini only*).

Assigned freight :
- Number of engines despatched.

Average time in terminus :
- In bound;
- Out bound.

Engine house :
- Mechanical Department;
- Transportation Department.

(Similar particulars are given for unassigned freight.)

CAR MILEAGE.

Freight loaded (*d*);
Freight Empty (*d*).
Per cent of loaded to total.
Passenger (*e*);
Caboose (*f*).

FREIGHT CARS.

Average number on line daily :
- Serviceable;
- Unserviceable;
- Number serviceable per 1 000 net ton-miles;
- Per cent unserviceable.

Number of days per average round trip :
- Under or awaiting repair;
- Loading (*g*);
- In-transit : loaded;
- Unloading (*g*);
- In transit : empty;
- In yards and sidings.

Total.

Average mileage per round trip :
- Loaded;
- Empty.

Car-miles per car day.
Net ton-miles per car day.

Maintenance costs :

Per 1 000 car-miles :

Labour;
Material;
Inspection.

Total.

Per car owned.

PASSENGER CARS.

Maintenance costs :

Per 1 000 car-miles :

Labour;
Material;
Inspection.

Total.

Per car owned.

YARD PERFORMANCE (selected yards).

Hours per day :

Yard engines;
Road engines.

Hours overtime worked by yard engines :

Cars handled :

Per day;
Per engine hour.

Wages cost :

Per yard engine hour :

Yardmasters;
Yard clerks;
Switch tenders;
Yard crews.

Total.

Total per car handled.

FREIGHT TRAFFIC.

Tons, revenue . . . . .
— company's service . . .
— total net . . . . .
— gross . . . . . } Daily average per mile of road operated.

Ton-miles, net. . . . . .
— gross . . . .
— potential. . . } Totals, and daily averages per mile of road operated.

Average haul per revenue ton.

Average number of trains daily per mile of road.

Total number of cars loaded (revenue traffic).

Average number of cars loaded daily (revenue traffic).

Average number of tons per car.

Average number of cars per train.

Average number of tons per train : Net;
— — — — Gross;
— — — — Per cent.

(Gross to potential.)

Average speed in miles per hour.

Costs per 1 000 gross ton-miles, and per train-mile (selected accounts) :

Enginemen's wages;
Fuel;
Engine house expenses;
Trainmen's wages;
Other locomotive and train supplies.

Total (selected accounts).

Gross ton-miles per freight train hour.

PASSENGER TRAFFIC.

Average number of passengers daily per mile of road.

Average number of passenger-miles daily per mile of road.

Average distance carried per passenger.

Average number of trains daily per mile of road.

Average number of revenue passengers per car.

Average number of cars per train.

Average number of revenue passengers per train.

Cost per train-mile (selected accounts) :

Enginemen's wages;
Fuel;
Engine house expenses;
Trainmen's wages;
Other locomotive and train supplies.

Total (selected accounts).

Cost per car-mile (total selected accounts).

COST OF FREIGHT HANDLED (*selected stations*).

Number of consignments.

Shed tonnage.

Office wages.

Shed wages.

Per cent of shed tonnage :
- Forwarded;
- Received;
- Transhipped.

Office wages per consignment.

Shed wages per ton handled.

MOTOR COACH STATISTICS (*include for each service separately*).

Number of passengers carried.

Motor coach service miles.

Trailer miles.

Revenue.

Cost of trainmen's wages. } Totals, and per motor coach mile.
— fuel and power . . } Totals, and per motor coach mile.
— lubricants, etc. . . } Totals, and per motor coach mile.
— repairs . . . . . } Totals, and per motor coach mile.

Number of motor coaches in service

Motor coach days :
- Serviceable in operation;
- Serviceable not in operation;
- Unserviceable.

Average daily mileage per serviceable motor coach.

Average mileage per gallon of gasoline or oil fuel.

Revenue per motor coach mile.

— per serviceable motor coach day.

Transportation expenses per serviceable motor coach day.

NOTES :

a) « Time » includes all trains conveying perishable, etc., traffic and running with an authorised tonnage reduction for speed.
« Dead » includes through freights not classifiable as time freight or way and local. « Way » covers local pick-up or pedlar trains which handle less-than-car-load merchandise, etc.

b) As different types of locomotives ranging from 12 000 lb. to 65 000 lb. tractive effort are in service in the various divisions or districts an equation of values has been found to be necessary. The actual mileage run by locomotives of each capacity is recorded separately and is equated to a common basis of 20 000 lb. tractive effort. For convenience in classification 100 000 lb. are regarded as the maximum, or 100 %, tractive effort and the equated figures are known as « 20 % capacity locomotive mileage ».

c) Separate figures are given for each class of engine.

d) The particulars are compiled for freight trains; mixed trains; special trains; transfers; and work trains separately.

e) The particulars are compiled for coach and combination sleeper, parlour and observation diner; express; and other car-miles separately.

f) The particulars are compiled for passenger and freight separately, and the latter figures are sub-divided as set out in (*d*).

g) As the actual time occupied in loading and unloading is not known the « Free » allowance time (*i. e.* : two days) is used for the purpose of dividing the freight car cycle into its chief elements.

Appendix E.

FRANCE

Particulars of statistics compiled on the Midi, Orleans, and Paris-Lyons-Mediterranean Railways.

MIDI RAILWAY.

The prime factors used are furnished in the first instance for the local use of the Operating Officers.

These partial figures when grouped serve as the basis for general statistics to be submitted to the Central Administration, and the results of these are shewn in a pamphlet called « Accounts and Statistics ».

Each department furnishes, independently, a series of statistics giving a statement of the expenditure debited to its particular budget.

Locomotive Running Department : gives the total expenditure separated under headings of wages, rolling stock, fuel maintenance, etc.

This expenditure is shewn per public train-kilometre, and is obtained :

a) from the monthly statement of kilometres run, consumption and bonus, relating to all locomotives and to public trains ;

b) from the Expenditure Sheet, giving the amount of the expenses involved for each operating account in the budget.

The statements thus compiled are monthly, but there is also an annual report which collates the results of the monthly statistics and shews the working expenses for the year in comparison with the results of previous years.

Permanent Way Department : furnishes several statistics relative to life of sleepers, consumption of metals, number of staff engaged in maintenance of way.

Movement Department : compiles.

Statistics shewing, with the total number of wagons on hand, the excess or deficiency of vehicles of various types at different points on the systems.

A statement shewing the exchange of stock with other systems.

A statement shewing wagon turnover, by fixing the average time under-load.

Two statements in connection with the running of passenger trains.

One shews the late running of trains, and the other (for certain trains only) the number of passengers making use of the trains.

Audit Department : compiles two series of statistics relating, one to passenger traffic and the other to freight traffic. For this purpose the following statements supplied by the stations are used.

A statement (monthly and annual) giving for the station in question the total number of passengers booked to each station on the system (local) and to each junction point (foreign).

An annual statement of « Petite vitesse » freight tonnage forwarded to each station in the system (local) and to each junction point (foreign).

General Accounts Department collates the results and submits to the Central Administration :

Statement of Gross Traffic Receipts per week and per month, compared with corresponding period in previous year.

Various statistics giving all useful infor-

mation as to working receipts and expenses, volume of traffic, numbers of and kilometres run by rolling stock, changes in rolling stock, census of staff

These latter particulars are inserted in the « Accounts and Statistics ».

ORLEANS RAILWAY.

The statistics compiled comprise the following data :

1. The volume of units of traffic in and out of each station, and the receipts for conveyance.
2. The number of and receipts from passengers, according to description of ticket, departing from each station and at each destination.
3. The receipts from « Grande vitesse » traffic, local to the system, forwarded from and received at each station.
4. The volume of each description of « Petite vitesse » traffic forwarded from each station.
5. Statement of tonnage, without distinction of category, forwarded from and received at each station.
6. Receipts from local « Petite vitesse » traffic, forwarded from and received at each station.
7. Receipts from foreign « Petite vitesse » traffic, in detail.
8. Number of consignments forwarded and received.
9. Forwarded « Petite vitesse » tonnage of certain commodities or numbers of live stock forwarded, arranged under headings of receiving systems and in groups of distance charged for.

Items 1 to 8 apply to the years 1900, 1913 and 1923. Item 9 has only been compiled since 1 July, 1920.

All these statistics are furnished to the Central Administration. No special statistics are compiled for the use of operating officers locally. If required, they make use of the tables enumerated above.

Apart from the modification of details in their compilation, these statistics (*i. e.* : Nos. 1 to 8) were compiled in 1900 and 1913 in the same form as they are at present.

PARIS-LYONS-MEDITERRANEAN RAILWAY

The statistics are compiled to provide the Central Administration with information as to the results of working in general, and bear upon the following various points :

Traffic statistics.

Passenger :

Total number of passengers and corresponding receipts in each class.

Average receipt per passenger in each class.

Ratio in each class per 1 000 passengers and per 1 000 francs of receipts.

Number of passengers and corresponding receipts according to description of ticket.

Number of passengers and corresponding receipts :

At full fares;

At reduced fares.

Number of passenger-kilometres and corresponding receipts :

At full fares;

At reduced fares.

Average fare charged per kilometre :

At full fares;

At reduced fares.

Average length of journey per passenger :

At full fares;

At reduced fares.

Number of passengers booked from each station on the system.

Baggage and dogs :

Tonnage (total weight and weight charged for) and corresponding receipts for baggage.

Number of and corresponding receipts for dogs.

« Grande vitesse » traffic :

Total tonnage conveyed (perishables, etc.) and corresponding receipts.

Number of postal packages and corresponding receipts.

Value of specie conveyed and corresponding receipts.

Number of vehicles, corpses, horses, and cattle, and corresponding receipts.

Receipts for storage and weighing.

Receipts for conveyance of mails.

Tonnage forwarded and received by each station (perishables, etc.).

« Petite Vitesse » traffic :

Total tonnage conveyed and corresponding receipts.

Number of vehicles, horses and cattle, and corresponding receipts.

Receipts for warehousing and weighing.

Tonnage and receipts of freight conveyed :
On traders' account ;
On Company's service.

Average receipt per ton of traffic conveyed :
On traders' account ;
On Company's service.

Ton-kilometres worked :
On traders' account ;
On Company's service.

Average haul per ton conveyed :
On traders' account ;
On Company's service.

Average receipt per ton-kilometre on freight conveyed :
On traders' account ;
On Company's service.

Tonnage forwarded and received by each station.

Tonnage of each commodity forwarded by each station.

Tonnage of « Petite Vitesse » traffic :
Between station and station ;
Between station and department ;
Between department and department,
according to traffic.

Tonnage, in distance groups, of traffic conveyed at the rates and under the conditions of transport applicable to special « Petite Vitesse » tariffs :

Distribution of all descriptions of receipts between the lines forming the system.

Weekly receipts.

Statistics shewing increase in rates.

Statistics of Expenditure.

Expenditure of the Main Departments concerned in working :

Traffic Department . . . . . } Wages.
Loco. Running Department . } Materials.
Permanent Way Department. }

General expenditure on working account of :

Expenses of Central Administration (all expenses).
Allowances to staff.
Compensation for accidents (staff and passengers).
Miscellaneous expenses.

General staff expenditure (under classified headdings) and ratio to total receipts.

Staff Statistics.

Monthly numbers of the establishment, arranged according to grade and rate of pay.

Actual numbers of staff at end of each month arranged according to grade and sex.

Distribution of staff at end of each year in various categories defined by formula H of the Railway Department of the Ministry of Public Works.

Monthly figures and corresponding graphs of :
Number employed in the theoretical establishment ;
Number of established employees actually available ;
Number of daily employees ;
Units of work performed.

Various annual figures relating to merit marks gained by employees in various grades and at various rates of pay.

Statement of employees moved by reason of service requirements who have not found housing accommodation at their new station.

Monthly statement of accidents and other occurrences, shewing derailments, collisions, and other mishaps and the number of employees and passengers killed and injured, as compiled by Departmental Headquarters.

Statement of broken couplings (with and without explanation).

Annual statistics of travelling facilities (passes and tickets at reduced fares) afforded to employees and their families for journeys over the principal French railways, other than the Paris-Lyons-Mediterranean and the Paris-Ceinture systems.

ROLLING STOCK STATISTICS.

Under classes of locomotives and vehicles.

TRAIN, ENGINE, VEHICLE AND TON-KILOMETRES (*for each line forming the system*).

Train-kilometres, *i. e.* ; Train-engine-kilometres for each description of train.

Engine (other than train-engine) kilometres [*i. e.* double heading, banking, light (including 2 or more running light together)] and shunting-hours for train purposes converted to kilometres at the rate of 10 kilometres per hour.

Vehicle-kilometres Paris-Lyons-Mediterranean and foreign) in all descriptions of trains.

Gross and effective ton-kilometres in all descriptions of trains.

Average load (gross and effective) of freight trains and wagons.

No statistics are compiled for local operating officers.

Appendix F.

GREAT BRITAIN.

Statistics rendered to, and published by, the Ministry of Transport, additional to, or in greater detail than, the particulars contained in the Annual Reports of the Railway Companies.

MONTHLY.

PASSENGER TRAFFIC.

Passengers (excluding season ticket holders) :

Number of journeys . . . . . — At full fares.

Receipts . . . . — At reduced fares : Excursion and weekend; Tourist; Workmen; Other descriptions.

Average receipt per journey . . — First, second and third class separately.

MONTHLY. (*Continued.*)

Season tickets :

Receipts from tickets issued during the month. — At full fares. At reduced fares : Traders tickets; Other descriptions. First, second and third class separately.

Parcels and miscellaneous traffic :

Quantities, receipts and average receipts per unit, for 18 principal descriptions of traffic.

MONTHLY. (*Continued.*)

FREIGHT TRAIN TRAFFIC.

Tons Net ton-miles Average length of haul Receipts Receipts per ton Receipts per ton-mile	For general merchandise and live stock; coal, coke and patent fuel; and other minerals separately. Under the headings of tons and net ton-miles, revenue traffic is distinguished from freehauled traffic.

Commodities :

Tons, receipts and receipts per ton, for 72 principal traffics.

Tons, receipts and average receipts per ton-mile, at each mile up to 50 miles, and in mileage groups beyond that distance, for a limited number of principal traffics each month.

Live stock :

Horses Cattle Calves Sheep Pigs Miscellaneous Total	Numbers conveyed.

ENGINE MILEAGE.

Train : Loaded Empty Engine and brake Total Shunting : By shunting engines By train engines Total Assisting required Assisting not required Light : Total (excluding departmental	Total mileage under each heading (coaching and freight separately) and percentage of Sunday working. In addition for shunting miles, assisting required miles, assisting not required miles, and light miles, the figures are worked out per 100 train miles. (Steam locomotives.)

MONTHLY. (*Continued.*)

Departmental :

Locomotive department Carriage and wagon department Stores deparment Ballasting Miscellaneous Total	Total mileage under each heading. and Percentage of Sunday working.

Total engine miles :

Steam engines Electric engines Steam, petrol, etc., rail motors Electric motor vehicles Departmental All traction	Coaching and freight separately.

ENGINE HOURS « IN TRAFFIC ».

Train Shunting Other (excluding departmental) Departmental Total	Total engine hours « in traffic » under each heading, (coaching and freight separately) and percentage of Sunday working.

Total engine hours :

Steam engines Electric engines Steam, petrol, etc., rail motors Electric motor vehicles Departmental All traction	Coaching and freight separately.

TRAIN MILES PER TRAIN HOUR AND PER ENGINE HOUR :

Steam engines Electric engines Rail motors Electric motor vehicles All traction	Coaching and freight separately.

MONTHLY. (*Continued.*)

WAGON MILES :

- Loaded.
- Empty.
- Total.
- Percentage loaded.

WAGON MILES PER :

- Train engine hour.
- Shunting hour.
- Total engine hour

WAGONS PER TRAIN :

- Loaded.
- Empty.
- Total.

AVERAGE WAGON LOAD (tons) :

- General merchandise.
- Coal, coke and patent fuel.
- Other minerals.
- Total.

AVERAGE TRAIN LOAD (tons).

NET TON-MILES PER :

- Train engine hour.
- Shunting hour.
- Total engine hour.

NET TON-MILES PER ROUTE MILE PER WORKING DAY.

LOCOMOTIVES, etc.

- Average number in stock on weekdays .
- Average stock available for use on weekdays :
  - Number . . . . . .
  - Per cent of stock. . .
- Average number in use (all services) on weekdays :
  - Number . . . . . .
  - Per cent of stock. . .
  - Per cent of average number available .

For steam locomotives, electric locomotives, steam rail motors, and petrol rail motors separately. Similar particulars are given for electric rail motor vehicles, except that motor vehicle car hours and motor vehicle car miles are substituted for engine hours and engine miles respectively.

MONTHLY. (*Continued.*)

LOCOMOTIVES, etc. (*Continued.*)

- Maximum number in use (all services) on any one day :
  - Number . . . . . .
  - Per cent of stock. . .
  - Per cent of average number available . .
- Engine hours « in traffic » per day per :
  - Engine in stock :
    - Weekdays. . . . .
  - Engine in use :
    - Weekdays. . . . .
    - Sundays . . . . . .
- Engine miles per day per :
  - Engine in stock :
    - Weekdays. . . . .
  - Engine in use :
    - Weekdays. . . . .
    - Sundays . . . . . .

Ditto.

CONSUMPTION OF COAL :

Pounds of coal consumed per engine mile :

- Passenger service . . .
- Freight service . . . .
- Shunting by shunting engines . . . . . .
- All services . . . . . .

For steam locomotives and steam rail motors separately.

CONSUMPTION OF LUBRICATING OIL :

Pints of oil used per 100 engine miles :

- Passenger service.
- Freight service.
- Shunting by shunting engines.
- All services.

Pints of oil used per 1 000 engine miles and per 100 000 gross ton-miles :

- Passenger service . .
- Freight service. . . .

For electric locomotives.

Pints of oil used per 1 000 motor vehicle miles and per 100 000 gross ton-miles :

- Passenger service . .

For motor vehicles.

MONTHLY. (*Continued.*)

ELECTRICITY USED FOR TRACTION PURPOSES :

Units used per engine mile and per 1 000 gross ton-miles :

Passenger service . . } For electric locomotives.
Freight service. . . . }

Units used per motor vehicle mile and per 1 000 gross ton-miles :

Passenger service . . } For motor vehicles.

TWO MONTHS IN EACH YEAR.

PASSENGER TRAIN TRAFFIC :

Excluding season ticket holders :

Passenger miles . . .
Average receipt per passenger mile . . .
Average distance per journey . . . . . } At full fares and at reduced fares. First, second and third class separately.
Season ticket holders :
Passenger miles . . .
Average receipt per passenger mile . . .
Average distance per journey . . . . . }

Passenger-miles per coaching train-mile.

Passenger-miles per train hour and per engine hour.

MARSHALLING YARDS.

Number of wagons detached . . . . . }
Engine shunting hours :
Train engines . . . .
Shunting engines . .
Total . . . . . } Separate particulars for 123 principal yards.
Number of wagons detached . . . . . }
Per total engine hour.
Per working day. .
Per train. . . . . }

TWO MONTHS IN EACH YEAR.

(*Continued.*)

MARSHALLING YARDS. (*Continued.*)

Hours on duty of shunting staff . . . . . }
Number of wagons detached per man-hour on duty of shunting staff . . . . . } Separate particulars for 123 principal yards.
Total wages paid to shunting staff. . . .
Number of wagons detached per £ of wages paid. . . . . }

GOODS STATION (SHEDS AND YARDS)

Total traffic dealt with.

Coal, coke and patent fuel . . . . . (tons) }
Goods and Livestock traffic :
Merchandise . . (tons)
Other minerals. —
Transfers . . . —
Live stock . . . —
Private siding traffic. . . . . —
Total. . . —
Total salaries and wages . . . . . (£) } Separate particulars for 122 principal stations.
Goods traffic handled by Company's staff.
Total tonnage . . . . .
Transfers, per cent of total tons. . . . . .
Average per ton handled :
Hours worked . . .
Wages paid . . . . .
Average weight per consignment . . . .

TWO MONTHS IN EACH YEAR.
(*Continued.*)

COLLECTION AND DELIVERY OF GOODS TRAIN TRAFFIC.

Horse vehicles.

Horses, average per working day:
- Total stock.
- Available, per cent of total stock.
- In use, per cent of number available.

Vehicles, average per working day:
- Total stock.
- Available, per cent of total stock.
- In use, per cent of number available.
- Under and awaiting repair, per cent of total stock.

Traffic carted.
- By one horse teams (tons).
- By two horse teams or more (tons).
- Total (tons).

Average per working day per:
- Working horse (tons)
- Working vehicle (tons).

Average weight per load:
- One horse teams (cwts).
- Two horse teams or more (cwts).
- Total (cwts).

Cost per ton:
- Operating.
- Overhead.
- Total.

Separate particulars for 94 principal stations.

TWO MONTHS IN EACH YEAR.
(*Continued.*)

COLLECTION AND DELIVERY OF GOODS TRAIN TRAFFIC. (*Continued.*)

Petrol vehicles.

Vehicles, average per working day:
- Total stock.
- Available, per cent of total stock.
- In use, per cent of number available.
- Under and awaiting repair, per cent of total stock.

Vehicle miles, average per vehicle in use per working day.

Petrol consumption:
- Vehicle miles. per gallon.

Traffic carted.
- Total (tons).
- Average per vehicle in use per working day (tons).
- Average weight per load (cwts).

Cost per ton:
- Operating.
- Overhead.
- Total.

Cost per vehicle mile.

Separate particulars for 54 principal stations.

Electric vehicles.

Similar information to that shewn for petrol vehicles is given for electric vehicles at a few stations where this class of vehicle is employed, except that the number of B. T. units of electricity consumed per vehicle mile is substituted for particulars of petrol consumption.

TWO MONTHS IN EACH YEAR.
(Continued.)

COLLECTION AND DELIVERY OF GOODS TRAIN TRAFFIC. *(Continued.)*

Steam vehicles.

Similar information to that shewn for petrol vehicles is given for steam vehicles at a few stations where this class of vehicle is employed, except that the quantity of coal or coke consumed per vehicle mile is substituted for particulars of petrol consumption.

SIX MONTHLY.

CONSTRUCTION OF ROLLING STOCK.

Orders placed :
- In Company's Shops .
- With outside firms . .
- Total. . .

Number completed :
- At Company's Shops .
- By outside firms . . .
- Total. . .

Number condemned, sold, transferred or converted . . . . .

Number ordered, but still to be completed.

Total stock . . . . . .

} Separate particulars for locomotives, passenger-carrying vehicles, other coaching vehicles, and merchandise and mineral wagons.

REPAIR OF ROLLING STOCK.

Number repaired :
- Heavy repairs . . . .
- Light repairs . . . .

Number at end of half-year :
- Under repair. . . . .
- Shop . . . . . .
- Shed . . . . . .

Awaiting repair :
- Shop . . . . . .
- Shed . . . . . .

Under and awaiting repair :
- Shop . . . . . .
- Shed . . . . . .

} Separate particulars for locomotives, passenger-carrying vehicles, other coaching vehicles, and merchandise and mineral wagons.

ANNUALLY.

FREIGHT TRAFFIC VEHICLES AND RAILWAY SERVICE VEHICLES OWNED BY RAILWAY COMPANIES.

Stock at 31 December :

Merchandise (other than special wagons) :
- Under 8 tons. . . . .
- 8 tons and under 10 tons. . . . . .
- 10 tons and under 12 tons. . . . . .
- 12 tons . . . . . .
- Over 12 tons and under 20 tons . . . . . .
- 20 tons and over (ordinary) . . . . . .
- 20 tons and over (bogie fitted) . . . . . .

} Open and Covered separately.

Mineral wagons :
- Under 8 tons.
- 8 tons and under 10 tons.
- 10 tons and under 12 tons.
- 12 tons.
- Over 12 tons and under 20 tons.
- 20 tons and over (ordinary).
- 20 tons and over (bogie fitted).

Special wagons :
- Vehicles built for special purposes.
- Cattle trucks.
- Rail and timber trucks.
- Miscellaneous.

Brake vans.

Railway service vehicles :
- Locomotive coal wagons.
- Ballast wagons.
- Other vehicles.
- Departmental locomotives.

ANNUALLY. (*Continued.*)

FREIGHT TRAFFIC VEHICLES AND RAILWAY SERVICE VEHICLES OWNED BY RAILWAY COMPANIES. (*Continued.*)

Capacity of traffic carrying vehicles.

Merchandise wagons : Open. . . . . Covered . . . . . Mineral wagons : Open. . . . . Covered . . . . . Special wagons : Wagons built for special purposes . . . . Cattle trucks. . . . . Rail and timber trucks Miscellaneous . . . . Total wagons. . .	Total tonnage capacity and average tonnage capacity per wagon.

Capacity of railway service vehicles.

Locomotive coal wagons . . . . . Ballast wagons. . . . Miscellaneous . . . . Total. . .	Total tonnage capacity and average tonnage capacity per wagon.

CENSUS OF STAFF. (One week in March.)

Number of persons employed . . . . . Average weekly salary or wage. . . . . Average weekly earnings	Separate particulars for principal grades.

Note. — The published returns shew the figures for Great Britain and for each principal company. In the case of the three largest companies the principal statistics are subdivided into operating areas.

Appendix G.

GREAT BRITAIN. — Sectionised wagon-mile return.

SHED AND TRAIN SECTION.	Wagon-miles.				Hours.				Train-miles.		Train-miles per train-hour.		Total wagon-miles per train-mile.		Total wagon miles per train engine-hour.		Loaded wagon-miles per train-mile.	
	Goods.		Mineral.		Train.		Shunting by train-engines.											
	Loaded.	Empty.	Loaded.	Empty.	Goods.	Mineral.	Goods.	Mineral.	Goods.	Mineral.	Goods	Mineral.	Goods.	Mineral.	Goods.	Mineral.	Goods.	Mineral.

Appendix H.

HOLLAND.

Particulars of statistics compiled.

FOR THE CENTRAL ADMINISTRATION.

Accidents to employees resulting in the payment of compensation.

Record of staff absences due to sickness.

Repairs and renewals of locomotives, number and cost.

Repairs and renewals of vehicles (coaching and freight), number and cost.

Production and expenses of gas plant.

Operation of cranes and coal stages.

Train delays, analysed under each cause of delay, at stations and en route.

Number of passengers in each class in specified trains (enumerated for one week in Summer and one week in Winter).

Actual and estimated monthly traffic receipts for coaching and freight traffic, and actual and estimated monthly traffic expenses.

Train-kilometres and receipts per train-kilometre for coaching and freight trains.

Gross receipts on different sections composing the system, separated as to *a*) passengers, *b*) luggage, *c*) freight, *d*) livestock and vehicles, *e*) special items, and *f*) telegraphs.

Kilometres of road operated, train-kilometres run, gross receipts (divided as above) shewn in total in relation to kilometres of road per year and per day and to train-kilometres, working expenses on a similar basis, the percentage of working expenses to gross receipts, various financial information as to rents, loans, sinking funds etc., the net income, and the distribution thereof between the companies and the State.

Number of passengers in each class and tonnage of freight conveyed by « Grande » and « Petite Vitesse » services; receipts for each of the above descriptions of traffic and for luggage.

Receipts from the various categories of tickets, per class and per passenger.

Tonnage of freight traffic conveyed monthly, local, international and transit.

Traffic dealt with at each station.

Average monthly receipts per kilometre per day.

Monthly receipts from the sale of contract tickets available over the whole system.

Quarterly receipts from the sale of contract tickets available between specified stations.

Quarterly number of contract tickets issued available over a section of the lines.

Monthly number of holiday tickets issued during the holiday period.

Quarterly number of bicycle tickets issued for singleseated machines.

Quarterly number of passengers passing between specified stations.

Monthly number of passengers conveyed by steamer between Harwich and Hook of Holland and between Folkestone and Flushing.

When a modified tariff is introduced for the conveyance of passengers and luggage, special statistics are compiled for a period shewing the monthly receipts, in order to enable a comparison to be made with the corresponding month in previous years.

FOR THE LOCAL USE OF OPERATING OFFICERS.

Engine-kilometres.

Engine failures.

Train delays due to engine staff.

Consumption of fuel and oil by locomotives.

Premium paid to drivers and firemen for economy in the use of fuel and oil and for avoiding train delays.

Water supplied by water companies.

Hot boxes.

Appendix I.

INDIA.

Particulars of statistics rendered monthly to the Railway Board.

STATEMENT 1 (1).

PASSENGER TRAIN PERFORMANCE
(*including a proportion of mixed train performances*).

Train-miles :
- Main lines : Passenger.
- — — Mixed.
- — — Total (passenger and proportion of mixed).
- Branch lines : Passenger.
- — — Mixed.
- — — Total (passenger and proportion of mixed).
- Total (passenger and proportion of mixed).
- Rail motor cars.
- Departmental.

Vehicle-miles :
- Passenger trains.
- Mixed trains.
- Departmental.

Shunting-miles :
- Shunting engines.
- Train engines.
- Total.

Engine-miles :
- Assisting not required.
- Assisting required.
- Light.
- Departmental.

Engine-hours :
- Main lines : Passenger train.
- — — Mixed train.
- Branch lines : Passenger train.
- — — Mixed train.

(1) Separate statements are required for broad and metre gauge lines.

STATEMENT 1 (1). (*Continued.*)

PASSENGER TRAIN PERFORMANCE. (*Continued.*)

Engine-hours (*continued*) :
- Shunting.
- Other.
- Departmental.

Average speed : (Passenger with proportion of mixed).
- Main lines : Train-miles per train engine hour.
- Branch lines : Train-miles per train engine hour.
- Total : Train miles per train engine hour.
- Total : Train miles per engine hour.

Shunting-miles per 100 train miles.

Light engine miles per 100 train miles.

Coal consumed :
- Total net tons : (Passenger and mixed).
- Lb. per engine-mile : (Passenger and mixed).

Lubricating oil used on engines :
- Total pints : (Passenger and mixed).
- Pints per 100 engine miles (Passenger and mixed).

(*To be posted on or before the 20th of the month following*).

STATEMENT 2 (1).

GOODS TRAIN PERFORMANCE
(*including a proportion of mixed train perfomances*).

Train-miles :
- Main lines : Goods.
- — — Proportion mixed.
- — — Total.

(1) Separate statements are required for broad and metre gauge lines.

STATEMENT 2. (*Continued.*)

GOODS TRAIN PERFORMANCE. (*Continued.*)

Train-miles (*continued*) :
- Branch lines : Goods.
- — — Proportion mixed.
- — — Total.
- Total : (goods and proportion of mixed).
- Departmental.

Shunting-miles :
- Shunting engines.
- Train engines.
- Total.

Engine-miles :
- Assisting required.
- Assisting not required.
- Light.
- Siding.
- Departmental : Locomotive.
- — — Engineering.
- — — Miscellaneous.
- Total : Departmental.

Engine-hours :
- Main lines : Goods train.
- — — Proportion mixed train.
- Branch lines : Goods train.
- — — Proportion mixed train.
- Shunting.
- Other.
- Siding.
- Departmental.
- Total.

Wagon-miles :
- Main lines : Loaded.
- — — Empty.
- — — Total.
- Percentage loaded of total.
- Branch lines : Loaded.
- — — Empty.
- — — Total.
- Percentage loaded of total.
- Total run on mixed trains.
- Departmental.

STATEMENT 2. (*Continued.*)

GOODS TRAIN PERFORMANCE. (*Continued.*)

Average speed :
- Main lines : Train miles per train engine hour.
- Branch lines : Train-miles per train engine-hour.
- Total : Train-miles per train engine-hour.
- Total : Train-miles par engine-hour.

Average train load :
- Main lines-wagons per train-loaded.
- — — — empty.
- — — — total.
- Branch lines, wagons per train loaded.
- — — — empty.
- — — — total.

Wagon-miles per wagon day.
Wagon miles per shunting engine-hour.
Wagon miles per engine-hour.
Shunting engine-miles per 100 train-miles.
Light engine-miles per 100 train-miles.

Coal consumed :
- Net tons : Goods train.
- — — Shunting including siding.
- — — Departmental.
- — — All services.
- Lb. per engine-mile : Goods trains.
- Lb. per engine-mile : Shunting (including siding).

Lubricating oil used on engines :
- Total pints (goods trains).
- Pints per 100 engine-miles (goods trains).

(*To be posted on or before 20th of the month following.*)

STATEMENT 3 (1).

PASSENGER AND GOODS TRAIN PERFORMANCE.
(*Figures based on ton miles.*)

Average wagon load :
- Coal.
- Other Merchandise.

(1) Separate statements are required for broad and metre gauge lines.

STATEMENT 3. (*Continued.*)

PASSENGER AND GOODS TRAIN PERFORMANCE. (*Continued.*)

Average train load :
Main lines : Net ton-mi'es per goods train mile.
— — Gross ton-miles per goods train-mile (including weight of engine).
— — Gross ton-miles per goods train-mile (excluding weight of engine).
Branch lines : Net ton-miles per goods train-mile.
— — Gross ton-miles per goods train-mile (including weight of engine).
— — Gross ton-miles per goods train-mile (excluding weight of engine).

Net ton-miles per wagon day.
— — per locomotive day.
— — per shunting engine hour.
— — per engine hour.
Gross ton-miles per engine hour.

Lb. of coal consumed per 1 000 gross ton-miles passenger trains (including proportion of mixed).

Lb. of coal consumed per 1 000 gross ton-miles goods trains (including proportion of mixed).

Density :

Passenger miles per running track-mile per day.

Net ton-miles per running track-mile per day.

(*To be posted not later than 55 days after the month to which the figures refer*).

STATEMENT 4 [1].

ROLLING STOCK PERFORMANCE.

Engines.

Average authorised stock (excluding engines ordered but not yet handed over to traffic)

[1] Separate statements are required for broad, metre and narrow gauge lines.

STATEMENT 4. (*Continued.*)

ROLLING STOCK PERFORMANCE. (*Continued.*)

Engines. (Continued.)

Average total number on line.

Average number under or awaiting repair :
Number.
Percentage of total number on line.

Average number available for use.

Average number in good repair stored.

Average number in use daily on :
Ordinary passenger service (including mixed)
Special service.
Goods service.
Departmental service.
Shunting including siding.
Total.
Spare.

Maximum number in use on any one day.

Number overdue repairs at end of the month :
Number.
Percentage of average authorised stock.

Engine miles per passenger engine per day.
— — per goods engine per day.
— — per day per engine in use.
— — per day per engine on the line.

Coaching stock.

Average authorised stock (excluding coaching stock ordered but not yet handed over to traffic) :
Passenger carriages
Other coaching vehicles.

Average number on the line :
Passenger carriages.
Other coaching vehicles.

Average number under or awaiting repair :
Passenger carriages.
Percentage of average number on the line.
Other coaching vehicles.
Percentage of average number on the line.

STATEMENT 4. (*Continued.*)

ROLLING STOCK PERFORMANCE. (*Continued.*)

Coaching stock (Continued.)

Number overdue repairs at end of month :
- Passenger carriages.
- Percentage of authorised stock.
- Other coaching vehicles.
- Percentage of authorised stock.

Goods stock.

Average authorised number of wagons owned. (Excluding wagons ordered but not yet handed over to traffic).

Average number of wagons owned :
- In units.
- In terms of four-wheelers.

Average number of wagons on the line daily pooled and non-pooled (in terms of four-wheelers).

Average number of unserviceable wagons on line daily :
- Number.
- Percentage of average number of wagons on line daily pooled and non-pooled.

Number overdue repairs at the end of month:
- Number.
- Percentage of average authorised number of wagons owned.

Total pints of oil used on passenger and goods stock.

Pints per 1 000 vehicle-miles (passenger and goods).

(*To be posted on or before the 20th of the month following.*)

STATEMENT 5.

REVENUE AND EXPENDITURE.

(*Approximate figures.*)

Route-miles.
Track-miles (excluding sidings).
Coaching earnings.
Goods earnings.
Other earnings.

STATEMENT 5. (*Continued.*)

REVENUE AND EXPENDITURE. (*Continued.*)

Total earnings.
Total working expenses.
Percentage of working expenses to gross earnings.
Total programme Revenue.

(*To be posted on or before the 25th of the month following.*)

STATEMENT 6, part I (1).

REVENUE AND EXPENDITURE (part I).

Route-miles.
Track-miles (excluding sidings).

Revenue.

Number of passengers originating :
- First class
- Second class.
- Intermediate class.
- Third class.
- Total.

Number of passengers carried :
- First class.
- Second class.
- Intermediate class.
- Third class.
- Total.

Passenger-miles :
- First class.
- Second class.
- Intermediate class.
- Third class.
- Total.

Earnings from passengers carried :
- First class.
- Second class.
- Intermediate class.
- Third class.
- Total.

(1) Separate statements are required for broad, metre and narrow gauge lines).

STATEMENT 6, part I. (*Continued.*)

REVENUE AND EXPENDITURE, part I. (*Continued.*)

Revenue. (Continued.)

Earnings from passengers carried (*continued*) :
- Total parcel earnings.
- Total miscellaneous coaching earnings.
- Total coaching earnings.
- Number of tons originating.

Number of tons carried :
- General merchandise (including live stock).
- Coal and coke for the public and foreign railways.
- Coal and coke on revenue account.
- Other revenue stores including materials for construction.
- Total.

Net ton-miles :
- General merchandise (including live stock).
- Coal and coke for the public and foreign railways.
- Coal and coke on revenue account
- Other revenue stores including materials for construction.
- Total.

Net ton-miles :
- General merchandise (including live stock).
- Coal and coke for the public and foreign railways.
- Coal and coke on revenue account.
- Other revenue stores including materials for construction.
- Total.

Earnings from goods carried :
- General merchandise (including live stock).
- Coal and coke for the public and foreign railways.
- Coal and coke on revenue account.
- Other revenue stores including materials for construction.
- Total.

Total other goods earnings.
Total goods earnings.
Total miscellaneous earnings.
Total gross earnings.

STATEMENT 6, part II.

REVENUE AND EXPENDITURE.

Revenue.

Increase (—) or decrease (+) in suspense.
Gross receipts.
Budget proportion of gross receipts.
Excess over (+) / Deficiency in (—) estimated gross receipts.

Expenditure.

Engineering Department.
Percentage of gross earnings.
Locomotive Department.
Percentage of gross earnings.
Carriage and wagon Department
Percentage of gross earnings.
Traffic Department.
Percentage of gross earnings.
General.
Percentage of gross earnings.
Steam boat.
Percentage of gross earnings.
Special and miscellaneous.
Percentage of gross earnings.
Total working expenses.
Total gross earnings.
Percentage of working expenses to gross earnings.

Programme revenue :
- Engineering Department.
- Locomotive Department.
- Carriage and Wagon Department.
- Other Departments.
- Total.

Percentage of working expenses to gross earnings.
Total net earnings.
Increase (+) or decrease (—) in suspense.
Gross expenditure.
Budget proportion of gross expenditure.
Excess over (+) / Deficiency in (—) estimated gross expenditure.

STATEMENT 7.

Commodity statistics.

Coal and coke.
Cotton, raw.
Cotton, manufactured.
Fodder.
Fruits and vegetables, fresh.
Rice in the husk.
Rice not in the husk.
Gram and pulse.
Wheat.
Jowar and Bajra.
Other grains and pulses.
Jute, raw.
Iron and steel, wrought.
Marble and stone.
Kerosene oil.
Oil seeds.
Tobacco.
Provisions.
Salt.
Gur, jagree, molasses, etc.
Sugar, refined and unrefined.
Wood, unwrought.
Metallic ores.
Railway materials.
Other commodities.

(Statements 6 (parts I and II), and 7 to be posted not later than 55 days after the month to which the figures refer.)

STATEMENT 9, part I.

TRAIN PERFORMANCE.

(2' 6" and 2' 0" lines of class I railways.)

Train-miles :
- Passenger.
- Mixed.
- Goods.
- Total passenger and proportion mixed.
- Total goods and proportion mixed.
- Rail motor cars.
- Departmental.

STATEMENT 9, part I. *(Continued.)*

TRAIN PERFORMANCE. *(Continued).*

Vehicle-miles :
- Coaching... Passenger trains.
- — Mixed trains.
- Goods.. .. . Loaded goods trains only.
- —. ..... Empty goods trains only.
- – ..... Total goods trains only.
- —..... Percentage loaded of total.
- —..... .. Total run on mixed trains only.
- Departmental.

Shunting miles :
- Shunting engines.
- Train-engines.
- Total.

Engine-miles :
- Other.
- Departmental.

Engine-hours :
- Passenger.
- Mixed.
- Goods.
- Shunting.
- Other.
- Departmental.

Average speed :
- Passenger trains... Train-miles per train engine-hour.
- Mixed trains..... Train-miles per train engine-hour.
- Goods trains..... Train-miles per train engine-hour.

Wagon-miles per wagon day.
Other engine-miles per 100 train-miles.

Coal consumed :
- Net tons... Passenger and mixed.
- — — ... Goods.
- — — ... All services (including Departmental).
- Lb. per engine-mile... (Passenger and mixed).
- — — ... (Goods).

Lubricating oil used on engines :
- Total pints (all engines).
- Pints per 100 engine-miles.

(To be posted on or before the 20th of the month following.)

STATEMENT 9, part II.

TRAIN PERFORMANCE.

(2' 6" and 2' 0" lines of class I railways.)

Average wagon load

- Coal.
- Other merchandise.

Average train load :

- Net ton-miles per goods train-mile.
- Gross ton-miles per goods train-mile (including weight of engine).
- Gross ton-miles per goods train-mile (excluding weight of engine).

Net ton-miles per wagon day.

Lb. of coal consumed per 1 000 gross ton-miles (passenger trains including proportion of mixed).

Lb. of coal consumed per 1 000 gross ton-miles (goods trains including proportion of mixed).

Density :

- Passenger-miles per running track-mile per day.
- Net ton-miles per running track-mile per day.

STATEMENT 8.

MONTHLY STATEMENT OF STATISTICS.

(For all except class I railways.)

Number of passengers carried :

- First class.
- Second class.
- Intermediate class.
- Third class.
- Total.

STATEMENT 8. *(Continued.)*

MONTHLY STATEMENT OF STATISTICS. *(Continued.)*

Passenger-miles :

- First class
- Second class.
- Intermediate class.
- Third class.
- Total.

Earnings from passengers carried :

- First class.
- Second class.
- Intermediate class.
- Third class.
- Total.

Other coaching earnings.

Total coaching earnings.

Number of tons carried.

Net ton-miles.

Earnings from tons carried.

Other goods earnings.

Total goods earnings.

Total gross earnings.

Total working expenses.

Total net earnings.

Percentage of working expenses to gross earnings.

Passenger train miles.

Mixed train-miles.

Goods train-miles.

Number of tons of coal consumed.

(Statements 8 and 9 (part II) to be posted not later than 55 days after the month to which the figures refer.)

Appendix J.

PORTUGAL.

List of statistics compiled by the Portuguese Railway Company.
(1900-1913.)

a) For the Chief Administration.

Passenger traffic.

Passenger journeys and receipts, in each class at full fares and reduced fares.

Average receipt per passenger, in each class, at full fares and reduced fares, and per kilometre.

Total passenger-kilometres.

Number of seats available per train and per kilometre.

Number of seats occupied per train and per kilometre.

Proportion of seats occupied to seats available.

Number of passengers passing *via* each frontier and distance travelled.

« Grande Vitesse » and « Petite Vitesse » freight traffic.

Comparison with previous year of freight conveyed, classified by description of goods and by sections of the Company's line.

Tonnage, ton-kilometres, total receipts, average receipt per ton and average receipt per ton-kilometre, for each section of line.

Tons and ton-kilometres *via* the two frontiers, shewing freight forwarded and freight received separately.

Expenses and receipts per unit of traffic

Utilisation of rolling stock.

Number of wagon days lost by wagons being detained in service by the Engineer's Department; by traffic department; on other Companies' lines; and similarly wagon-days lost by other Companies' wagons on the Company's line.

Total wagon-kilometres worked by :

a) Company's wagons over the Company's system and other Companies' systems;

b) Other Companies' wagons over the Company's system.

Utilisation of rolling stock. (Continued.)

Number of kilometres worked over the Company's system by empty wagons, by the Company's and other Companies' wagons.

Number of journeys over the Company's system made by each wagon.

Ratio of empty wagon-kilometres to total wagon-kilometres.

Average wagon-kilometres worked per day.

Ton kilometres carried.

Average load per wagon.

Number of wagons in revenue freight service.

b) For the use of Local Executive Officers.

Passenger traffic.

Annual number by stations of origin, class, description of ticket and between pairs of stations.

Number and distance travelled between two adjacent stations, and passenger-kilometres by sections of line.

Annual number of passengers, in classes, at transit stations.

Annual number of pieces of luggage, dogs and bicycles, by stations of origin and by sections of line.

« Grande Vitesse » and « Petite Vitesse » freight traffic.

Annual number of kilogrammes by stations forwarding and receiving, and by classes of freight.

Annual number of kilogrammes between pairs of stations.

Tonnage between two adjacent stations, and ton-kilometres by sections of line.

Number of consignments forwarded by each station.

Annual tonnage of freight, « Grande Vitesse » and « Petite Vitesse » by classes, at transit stations.

Movement of locomotives, trains and rolling stock.

(*1923.*)

The statistics now published comprise those shewn under *a*) and *b*) above, no distinction being drawn between the data supplied to the Administration and other figures.

Appendix K.

SWEDEN.

Particulars of monthly statistics.

Length of line operated.

Stock of locomotives, coaching vehicles and wagons.

Number of locomotives available for service.

Engine-kilometres :
- Train;
- Shunting;
- Reserve.

Vehicle-axle-kilometres, by coaching, freight, mixed etc. trains.

Wagon-axle-kilometres, loaded and empty.

Locomotive fuel consumption.

Special statistics of electric traction.

Number of wagons loaded.

Number of wagons supplied and demanded (daily average).

Passenger journeys and receipts.

Mail traffic receipts.

Freight tonnage and receipts.

Miscellaneous receipts.

Expenditure.

Census of staff.

Derivative statistics :
- Vehicles per train ;
- Engine-kilometres per engine per day ;
- Average time of circulation per wagon ;
- Various averages of receipts and expenditure ; *e. g.* :
  - per kilometre of line ;
  - per vehicle-axle-kilometre ;
  - per engine-kilometre, etc.

In addition, tonnage and number of wagon loads of about 60 groups of commodities are reported quarterly, and special reports are also compiled from time to time giving further details of fuel consumption per train-kilometre and per vehicle axle-kilometre.

Most of the above particulars are given for the five districts and the State Railways as a whole.

Separate figures are also compiled relating to steam ferries, the mineral line serving the Lapland ore-fields, and other specialised industries which require individual treatment for the purpose of accounts and statistics.

Appendix L.

SWEDEN.

Statistics published in the Annual Report.

a) State Railways as a whole.

b) Five districts.

c) About 30 statistical areas.

(Some particulars are only given under heading [*a*]).

Capital, capital expenditure, length of line and other particulars of permanent way and buildings, stock and capacity of locomotives and vehicles.

Train, engine, and vehicle-kilometres, in detail.

Fuel consumption and locomotive running expenses.

Gross ton-kilometres for each description of train.

Use of equipment :

Engine-kilometres per locomotive per annum ;

Average number of vehicles per train ;

Average weight per train ;

Per cent of available capacity utilised per vehicle ;

Per cent of empty haulage for wagon stock.

Passenger-kilometres and net ton-kilometres, average journey and haul, various descriptions of passengers and commodities conveyed in distance-groups.

Passenger journeys, tonnage of freight, commodity tons and ton-kilometres in 60 groups.

Passenger, mail, freight and miscellaneous receipts.

Operating expenditure.

Census of staff and wages paid.

Station statistics.

Accidents.

Derivative statistics :

Numerous statistical averages and comparisons are given, based on the particulars shewn above.

From the total receipts and expenditure the net income is ascertained and shewn in relation to the capital invested.

In addition, the same figure is shewn for various parts of the system, the effect being to shew that in the south, where traffic is dense, there is a surplus, but in the north, where lines have been built for national development and are not yet remunerative at the necessarily low tariffs in operation, there is in many cases a deficit.

[625. 616]

REPORT No. 1

(America, Great Britain and colonies)

ON THE QUESTION OF TRACTION FOR LIGHT RAILWAYS (SUBJECT XV FOR DISCUSSION AT THE TENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION), (1)

By Brigadier-General H. O. MANCE, C.B., C.M.G., D.S.O.,
LATE DIRECTOR OF RAILWAYS, LIGHT RAILWAYS & ROADS, WAR OFFICE (ENGLAND).

The list of questions shown in appendix A was sent to all the members of the Association in America, Great Britain and the British Dominions and Colonies. Out of forty-three replies twenty-nine were to the effect that no useful information was available. I have, therefore, supplemented the information given in the replies by reference to the technical press and by personal correspondence and discussion with authorities on the subject.

The number of light railways, in the Continental sense, in America and Great Britain is extremely limited while feeder lines to Colonial railways are usually considered to be part of the main system unless constructed to a narrow gauge. (Several of the replies received dealt with such narrow gauge branch lines.) I would, therefore, suggest that in order to keep in touch with the development of rail motor traction in these countries it would be desirable not to limit the subject of railway motor traction to « light railways ».

The points to which I venture to draw your attention are :

A. — The present situation as regards rail motor traction.

B. — Traction for narrow gauge light railways.

C. — The road rail system.

A. — In England rail motor traction has made comparative little headway. This may be due to following causes. On most English branch lines provision has to be made for a fairly heavy milk service and also for the movement, by passenger train, of horse boxes. Periodical increases of traffic, such as on market days, have also to be provided for, so that the occasional use of trailers would be necessary if rail motor traction were adopted. In this connection the chief advantage of a rail motor car — its lightness — conflicts with its development as a tractor. It must also be remembered that there is almost invariably a goods service to be provided for, involving both shunting at the terminus and haulage along the branch line. As a result branch lines are normally worked by the smaller types of steam tank locomotive in use on the railway. In one such case the current running costs were reported to be made up as follows (in pence per engine mile) : personnel, 9.91; fuel, 6.88; running stores, 0.39; maintenance, 4.43; total, 21.61. A number of rail motor cars exist in England (*vide* appendix B) but these are almost entirely steam cars.

Where frequency of service is required in the suburban areas of large towns the extension of the traffic is likely in the future to justify electrification.

(1) This question runs as follows : « *A*) Special systems of traction for light railways. — *B*) Rail motor traction. »

Meanwhile, owing to the saving in occupation of the line at the terminals, such services are dealt with, particularly on the Great Western Railway, by steam auto trains of four coaches with a small loco in the centre controlled from either end. Outside suburban areas it is possible that a field may be found for the use of rail motors in providing an improved frequency of service on lines where it is necessary to compete with a road passenger service. It should be noted that the adoption of light petrol driven rail cars requiring only one driver would necessitate negotiation with the Labour Unions. The roads in England are good and there is a tendency for the railways to establish road motor services to outlying points as feeders to the Railway rather than to construct new light railways.

In America the situation appears to be quite different. A large number of short lines exist on which the traffic is very light so that ordinary steam traction has proved to be wastefully extravagant. Petrol driven cars are being developed to meet these conditions. The present tendency is to discard the heavier type of car which was originally made, and which was probably too experimental to establish itself, and to concentrate on light rail cars, following, as far as possible, established practice in road motor vehicles. As far back as 1922 some of these light cars were reported to have run 500 000 miles in five years service at an operating cost of from 10 to 25 cents per mile and with a petrol consumption of from 5 to 10 miles per gallon. The maintenance costs were reported to be as low as $15 per month for small cars with a 2 1/2 to 3 ton motor chassis, and only slightly more for a 5 ton chassis. The figures of one of the larger types of car costing $12 500 operated by two men and running 100 miles a day would work out at :

	Cost per mile.
Petrol	$0.030
Labour : 2 men at $125 per month	0.085
Depreciation at 12 1/2 %	0.042
Interest and insurance	0.022
Maintenance	0.021
Total	$0.200

The labour in this case consisted of young men capable of carrying out light repairs and paid at a lower rate than steam locomotive drivers.

The following table purports to give comparative costs of steam train and petrol rail car operating on two fairly typical short light railways in the U.S.A. on the basis of petrol at 28 cents (1/3 ½) per gallon.

	RAILROAD « A »			RAILROAD « B »		
	Steam train.	Large railcar.	Small railcar.	Steam train.	Large railcar.	Small railcar.
Daily mileage	150	150	150	70	70	70
Number of crew	5	2	1	5	2	1
Seating capacity	120B	36B	31	90B	36B	31
Wages	$46.00	$17.50	$10.00	$32.42	$17.50	$10.00
Fuel	41.25	5.25	4.20	32.20	2.45	1.96
Repairs	32.75	2.00	2.00	26.50	0.95	0.95
Supplies & Exp.	6.00	2.00	2.00	3.00	1.75	1.75
Ditto, Loco. or chassis	2.65	0.56	0.50	1.68	0.45	0.35
Lubrication	0.60	0.60	0.19	0.35	0.30	0.13
Roundhouse	7.00	0.80	0.80	8.68	0.80	0.80
Repairs, car or body	6.75	3.00	2.00	2.80	1.50	1.50
Total per day	$143.00	$31.71	$21.68	$109.63	$25.70	$17.44
Cost per mile	0.95	0.21	0.14	1.56	0.38	0.25

The most satisfactory construction has been a single pair of drivers with leading pivoted axle or bogie. The light six-wheeled type cars up to a lenght of 36 feet and a weight of 20 000 lb. can be operated at a speed of from 30 to 35 miles per hour and 5 to 6 miles per gallon of petrol. This type is considered the most suitable for carrying up to 35 passengers and about 2 000 lb. of luggage.

As regards Colonial railways, the New South Wales Railways have adopted the petrol driven motor on some six branch lines of standard gauge totalling 395 miles, in order to give the inhabitants of a rather sparsely populated district as frequent a train service as possible when the business offering does not warrant a regular schedule of steam trains. The service has been reported to be a financial success and is to be further developed in consequence. A history of its development may be of interest. The first rail motor used on this railway was a converted four cylinder 50 H. P. Moreland road lorry. The wheels and body of the lorry were removed, the chassis lengthened and a passenger body built on the same. A four wheel bogie with a wheel basis of 4 ft. 3 in. was substituted for the front axle and special steel wheels 42 1/2 inches in diameter were constructed for the rear axle and the gear ratio altered to 3 7/8 to 1. A wheel hand brake was fitted to operate on the four wheeled bogie, the motor car foot brake still remaining in operation on the rear wheels. The tare weight of the vehicle is 7 tons, 16 cwt., 2 qrs. and accommodation is provided for 33 passengers. To provide for cream traffic a small trailer car was built with a capacity of 3 tons and a tare weight of 3 tons, 9 cwt., 3 qrs. The average speed of the rail motor, including stops, is 19 1/4 miles an hour, the maximum speed being 25 miles an hour.

The next development was to design a six cylinder reversible petrol engine of 105 B. H. P. at a normal speed of 1 000 revolutions per minute, corresponding to a road speed of 30 miles an hour but capable of giving 160 B. H. P. at 1 600 revolutions. This engine is mounted under an ordinary steam service suburban car with a seating capacity of 55 and the total tare weight is 26 tons, 7 cwt., 2 qrs. It was realised that with a specially built car the weight could be appreciably reduced. The following further particulars may be of interest.

The engine itself consists of two blocks, each having three cylinders 5 1/4 inches in diameter by 6-inch stroke. Overhead valves lying at 10° inclination to the centre line, and driven by an overhead cam shaft, are provided. This shaft is fitted with two sets of cams, either of which may be brought into use, thus enabling the engine to be run in either direction, and obviating the necessity of turning the car at terminals. Engine starting is by compressed air, the air being admitted to the cylinders by a distributor until the engine starts. A hand starter is provided in the event of lack of air pressure. The motor is equipped with Remy ignition, power being obtained from batteries which are kept charged by a small unit « Stone » generator, which also serves the headlights and car lights.

Forced feed lubrication is employed throughout the engine, the pressure valve being interconnected with the throttle to provide for different variations in load. Two Zenith Carburettors are fitted, serving the cylinders through a common induction pipe.

The engine is water cooled by means

of a pump, and two radiators having removable sections. These are provided with two four-bladed fans to assist in circulating air through the fins, and are mounted beneath the floor on either sides of the engine at right angles to the motion of the car.

The drive is taken from the engine by a dry multiple disc clutch, having seven driving and eight driven plates, through an epicyclic gear box giving three speeds to a propellor shaft which drives, by an overhead worm gear, the two axles of one of the bogies, such having been specially strengthened. To counteract uneven wheel wear differential motion is provided between the axles.

The engine is slung in the centre of the car in such a position as to bring the centre line of the drive in practically a straight line when the car is loaded. This necessitates the cylinder heads and valve gear projecting through the car floor. They are, however, covered by a casing which provides seating for five persons. The engine also drives an air compressor for Westinghouse brake and starting.

The controls, located at both ends of the car, consist of : a Westinghouse brake drivers' valve, clutch pedal, reverse lever, three speed quadrant and lever, foot accelerator, spark control and hand brake; also a speedometer and Westinghouse brake duplex gauge and (engine) oil pressure gauge.

Subsequently five further cars were manufactured locally to the following design :

Length over all	44 ft. 8 in.
Length over body	42 ft. 0 in.
Width over mouldings	9 ft. 8 in.
Height from rail level to top of roof	11 ft. 6 1/4 in.
Centres of bogies	28 ft. 0 in.
Bogie wheel base	5 ft. 0 in.
Diameter of driving wheels	2 ft. 8 in.
Diameter of trailing wheels	2 ft. 1 in.
Rated horse power	72
Total weight (empty)	11 t. (approx.).
Speed on top gear on tangent track	35 miles per hour.

The design has been specially prepared to combine maximum capacity with minimum weight. The all-steel underframes consist of modified Warren Truss Girders entirely constructed by electric arc welding. The weight of the underframe complete with engine gear box, air compressor and electric generator totals somewhat under 3 tons.

The body weighing 5 tons is constructed of Australian woods, and the bogies are built of steel plate pressings and rolled steel sections. The wheels are of a special type constructed from light pressed steel discs bolted to suitable hubs and tyres.

The driving compartments fitted at both ends are equipped with all control apparatus necessary for the operation of the car, being duplicates of Rail Motor No. 2.

A guard's compartment 9 ft. 4 3/4 in. in length is located approximately in the centre of the car, which divides the passenger accommodation into two main compartments, one providing 24 and the other 21 seats. The guard's compartment is fitted with sliding doors on either side, each giving a clear opening of 3 ft. 6 in. in width. Provision is made in this compartment for 3 tons of luggage and goods, and in cases of crush loading auxiliary seats can be made available here for the accommodation of 7 additional passengers, thus bringing the total seating capacity up to 52. The seats in the main compartments are well sprung and upholstered in leather, the arrangement being the same as in the newer type suburban cars, one side accommodating three and the other two. Access is given to the compartments by

swing doors 26 inches wide, located one near each end of the car.

The engine is located below a suitable hatchway in the centre of the Guard's compartment. This engine is a six cylinder water-cooled Thornycroft (Z 6), and is mounted on the under-frame below floor level. It is rated at 72 H. P. at 1 400 revolutions per minute, the fuel being benzine. Provision is made for four speeds in both directions, and the weight of the engine with gear box is 15 cwt. The radiators are alongside the engine, cooled by a fan driven from the engine by a belt drive.

Straight Westinghouse airbrakes are fitted, the air being supplied from an automatically controlled geared compressor, which is directly coupled to the engine, the displacement capacity being 10 cubic feet per minute.

The automatic starter consists of an air operated device attached to the engine, and supplied with air from the main air reservoir. An emergency hand operated starter is also fitted.

Electric supply for the 16-volt lighting circuits for both car and head lights is provided from an 8-cell storage battery, which is charged by a suitable dynamo driven from the engine shaft.

It is now proposed to proceed with the construction of a further five cars which will be similar to the above, with the exception that they will be equipped with a more powerful engine in order that they may haul a trailer car.

No figures are available as to the cost of working. With a view to saving fuel costs the use of two-stroke semi-Diesel engines is under consideration.

The South India Railway are also working two petrol driven rail motors in order to carry a heavy shuttle service third class passenger traffic on a section of metre gauge railway with flat grades and curves. These vehicles each convey 70 passengers and luggage at 15 miles an hour with a petrol consumption of 9 miles per gallon. No trailers are used; the personnel consists of one driver and one guard. The cost per vehicle in 1915 was about £1 400 and the running cost is made up as follows : (in pence per car mile) personnel, 0.50; fuel, 3.00; running stores, 0.33; maintenance, 0.58; total, 4.41.

The South African and certain other railways are also experimenting with steam and petrol driven rail motors for branch lines. Promising results are reported from South Africa with an experimental 100 H. P. producer gas engine. A 400-500 H. P. machine is now under construction.

The successful introduction of steam rail motors on the Jersey Railways also deserves notice. Particulars of some of the rail motor cars referred to above are shown in appendix C.

It has already been mentioned that the use of trailers has not so far proved very successful. It has been suggested that to provide for the haulage of extra vehicles and for the handling of goods traffic on lines for which rail motors are otherwise well adapted, a commercially practicable petrol locomotive, which has yet to be proved. might be the solution, but in this, as well as in the development of the larger petrol passenger car, the question of transmission will probably prove one of the principal difficulties to be surmounted. There will undoubtedly be a demand for more powerful cars to deal with the growing traffic on lines which have successfully used the present type of light car. It has been suggested that the most promising development will lie in adhering strictly to the successful and proved type of motor and increasing the power by increasing the number without alter-

ing the size of the cylinders. A recent development consists in the adoption of electro-pneumatic control instead of direct mechanical controls as hitherto used, which were merely adaptations of the road vehicle control. This electro-pneumatic control not only permits the car to be operated from either end, but will permit the adoption of two power units on each car, or two cars to be coupled together as a train and operated by a single motor man. If successful, this development will at once increase the field of utility of the rail motor to an enormous extent.

The Diesel electric rail car has not yet been seriously tried in America or on Colonial Railways. It has, however, been envisaged as the possible solution for higher powered units.

B. — Traction for narrow gauge lines, *viz.* 2 ft. 6 in. and 2 feet.

It is well known that there is in India a considerable mileage of 2 ft. 6 in. railways, some of it laid in rails up to 40 pounds a yard and equipped with powerful 8 coupled locomotives carrying a heavy traffic. For example, the Bengal Nagpur Railway 2 ft. 6 in. feeder lines carry on an average some 60 to 70 thousand tons of goods and 215 000 passengers per month. On grades of 1 in a 100 the maximum train load is 22 vehicles and 500 tons gross. The speeds run are up to 30 miles an hour and coal consumption 71 pounds per train mile. In the British Colony of Sierra Leone the main line is 2 ft. 6 in. gauge. The cost of working of some of these 2 ft. 6 in. lines as reported is summarised in appendix D, together with corresponding particulars of a metre gauge feeder line in India and of a 2 foot gauge feeder line in South Africa, where the difference in labour costs is very striking. I do not, however, propose to deal further with these cases which, while useful as a basis of comparison, follow the normal steam practice.

During the war narrow gauge lines, chiefly 60 centimetres (2 feet) gauge, were developed to an unprecedented extent and it may be asked whether this development produced any results of value for economic purposes. These light railways were used chiefly to carry the very heavy requirements of a modern army under conditions of stationary warfare in the forward areas beyond the broad gauge rail heads. The haul, therefore, rarely exceeded from 8 to 10 miles. The maximum traffic carried on 60 centimetres light railways in the British Army area on the Western Front was 200 000 tons in one week. A large proportion of the traffic consisted of ammunition and other heavy materials. Grades were steep so that one of the principal requirements was the maximum tractive effort compatible with a hastily laid track. The British type of track which was necessarily light to economise steel and to facilitate handling was standardised at a 20 pound rail normally laid on broad steel sleepers. It was also of importance in many situations to render the movement as inconspicuous as possible by the suppression of smoke, and to afford armour protection against shell splinters. To meet with these conditions the following forms of traction were developed :

1. — Steam locomotives.

Particulars of these are summarised in appendix E. The lighter 6 coupled locomotives with a working weight of 7 tons were well adapted to the track but had

not the desired tractive power. The heavier side tank 4-6-0 locomotives, weighing up to 14 1/2 tons, conveyed the desired loads but at the expense of very heavy track maintenance. The side tanks were also found to make the engines top-heavy and were in many cases removed and converted to tenders. It will be seen later that these locomotives have since done well on a heavier track.

II. — Petrol electric locomotives.

These locomotives were intended to take the place of the heavier steam locomotives where it was unadvisable to show smoke. They were, moreover, ordered at a time when it was impossible to obtain delivery of sufficient steam locomotives to meet requirements. These machines were originally designed as articulated 0-4-4-0 tractors, each worked by a 60 H. P. petrol electric set, but were subsequently designed as separate 0-4-0 tractors. Owing to the demands of aircraft and road traction it was only possible to allot 40 H. P. and 45 H. P. engine to these tractors which suffered accordingly. The 500 volt generator developed 30 kwt. at a speed of 1 000 revolutions. The working weight of the tractor was 8 tons and under test they could haul 40 tons up a 1 in 33 grade at 3 miles an hour. A certain amount of armour protection was afforded. They fulfilled their purpose satisfactorily, and though their maximum load was no greater than that of the 40 H. P. petrol tractor referred to below they were easier to drive and less liable to stall on a steep grade; but the arrangement of the under carriage was somewhat rigid for a badly maintained track. They are, however, too complicated and expensive for commercial working on so small a gauge.

III. — Petrol tractors.

Perhaps the most interesting development was in the use of 20 and 40 H. P. petrol tractors for distributing traffic in the forward areas over a badly maintained track. The original 20 H. P. tractor was designed to run on a 9 pound rail and weighed 1 ton, 18 cwt., having a drawbar pull of 1 193 pounds. When the track was strengthened the gross weight of these tractors was successively increased to 2 ton, 16 cwt., the drawbar pull being 1 650 pounds. The tractor was specified to haul 15 tons gross up 1/33 at 4 miles per hour. In practice it could start and pull a load of 7 loaded one-ton tip waggons up a gradient of 1 in 40 at about 10 miles an hour. It was essential that the tractor should be capable of being driven both ways and the design was much simplified by arranging for the driver to sit sideways, so that he could use the same levers and operating gear in either direction. The engine was put crossways, thus facilitating direct drive by chains on both axles and avoiding all right-angled bends, bevel gearing, coupling rods, etc. Instead of two end radiators which, in practice, were continually being damaged a single fan-cooled radiator pointing fore and aft was adopted and operated equally well in both directions. The 20 H. P. tractor had two cylinders, 4 1/2 inches (115 mm.) diameter, 5 1/2 inches (140 mm.) stroke. The full range of the tractor's speeds was from 2 to 12 miles an hour. Screw brakes on all 4 wheels. These tractors have since been considerably used for hauling tip waggons, etc., on engineering works. The success of these small tractors led to a demand for something heavier and a 40 H. P. four cylinder machine was designed on exactly the

same lines, but the engines were arranged to go underneath the driver's seat. Heavy skid bars were arranged underneath the chassis to prevent the tractor going off into the mud when it was derailed. These tractors were all more or less armoured. The could haul 38 tons up 1 in 33 at 4 miles per hour. They were manufactured by the Motor, Rail and Tram Car Company of Bedford. Consulting engineers Messrs. Rendel, Palmer and Tritton. A number of these 20 and 40 H. P. tractors are in use on the feeder lines of the Buenos Aires Great Southern Railway. It may be interesting to note in passing that open waggons were employed for these 60 centimetres (2 foot) lines capable of taking a load of 10 tons, 11 cwt., 3 qrs. and having a tare weight of only 2 tons, 8 cwt., 1 qr.

IV. — In order to provide for breakdown and inspection work and for conveying light loads at comparatively high speeds a number of Ford car chassis were successfully converted to run on a 60 centimetre track. The Ford chassis with the wheels removed was mounted on a 4-wheeled railway trolley, one axle of which was driven by chains from the rear axle of the Ford car.

Buenos Aires Great Southern Railway.

Since the war the Buenos Aires Great Southern Railway have constructed over 330 kilometres (205 miles) of 60 centimetre feeder lines on which a good deal of ex-British war material is employed. These lines serve grain and potato districts. The majority of the track consists of 20 pound rails laid on 6 to 8 steel sleepers to the rail length of 15 feet. Maximum grade outward 1/80, inward 1/150. Minimum curvature 50 m. (2 1/2 chains) used sparingly. In the potato zones heavier rails are used and on these sections the traffic is hauled by 4-6-0 Hunslet locomotives referred to above, tenders being substituted for side tanks and oil fuel for coal in some cases. The Hunslet locomotives are not run on the 20 pounds track as this is found to necessitate excessive maintenance. In the cereal areas the traffic is entirely carried out by 20 H. P., 40 H. P. and 45 H. P. petrol tractors which are found to have the following advantages :

a) The serious problem of avoiding fires even in the driest summer months is completely solved;

b) Owing to the seasonal nature of the traffic extra drivers have to be taken on for the rush periods every year and these are easier trained to work the petrol tractors than locomotives;

c) The traffic is liable to spasmodic fluctuations and the number of unemployed men who have to be paid during the periods of minimum traffic is less with tractors than with locomotives;

d) Owing to a large percentage of salts the water question for locomotives would be very difficult to cope with.

The tractors are, however, more expensive in repairs than the locomotives. The consumption of petrol per kilometre is heavy, *viz.* :

	Litres per kilometre.	Miles per gallon.
20 H. P.	1/2	5.7
40 H. P.	3/4	3.8
45 H. P.	7/8	3.2

The consumption of coal by the locomotives is at the rate of 10 kilogrammes per kilometre and of oil 6 kilogrammes per kilometre (35.5 and 21.3 lb. respectively per mile). The 20 H. P. tractor

trains are worked by one man only and the 40 and 45 H. P. tractor trains by one driver and one guard. The Hunslet locomotive requires a fireman in addition. The maximum speed of the tractors is about 14 kilometres (8.7 miles) an hour and the locomotives can reach 25 kilometres (15.5 miles) an hour but are normally limited to 18 kilometres (11.2 miles), as there is too much oscillation of the train at higher speeds. The maximum gross and net loads are :

	Vehicles.	Gross load.	Net load.
20 H.P.	6-8	65	51
40 H.P.	10-15	111	84
45 H.P.	12	130	97.8
Hunslet loco. . . .	17	204	153.4

The cost of running in pence per ton mile for the two zones is given as follows :

	Potato zone. (Steam loco.)	*Cereal zone.* (Petrol tractor.)
Running costs; fuel and personnel.	1.6 d.	1.45 d.
Repairs and maintenance of locos and tractors.	0.22 d.	0.55 d.
Repairs and maintenance of wagons	0.19 d.	0.14 d.
Maintenance of track	0.35 d.	0.53 d.
Total costs. . .	2.36 d.	2.67 d.

The system is still in its infancy but with increased experience more economical working is anticipated.

Estate Railways.

The above developments have undoubtedly given an impetus to the utilisation of narrow gauge railways for the collection of produce on large estates as an alternative to road traffic. It is interesting to note that the usual types of petrol tractors with high speed engines are considered to be too complicated for such purposes and recent developments are in the direction of a single cylinder, slow running horizontal type of engine, the cooling being by evaporation by thermo-syphon communicating with a large cool water tank, the power being transmitted from the engine shaft by gears and friction disc clutches, giving two speeds in each direction, to a heavy driving shaft with rod couplings. This type as designed by Messrs. Theakston can be made from 10-12 H. P. weighing 3 tons, 18 cwt. up to 35 H. P. with a working weight of 8 tons. Engine speed in each case, 300 revolutions per minute. Paraffin consumption averaging 3/8 pints per H. P. hour. It has the merit of being practically foolproof and the smaller size is intended to work on an 18 pound track such as is now being standardized for estate work.

C. — Finally, we may turn to the problem which not infrequently faces Colonial Railway Administrations of collecting produce over difficult country from sparsely inhabited areas, situated either beyond the range of economic road transport or where, for example, owing to the tetse fly, animal transport is not possible. In easy country light feeder lines of the same gauge and laid with second-hand material from the main lines may prove the best solution. In this case traction would normally be effected by ordinary steam working. Alternatively the traffic may be carried by narrow gauge feeder lines, the traction on which has already been dealt with. In localities, however, where a surface line necessitates grades of over 3 % and where, with normal adhesion, the required tractive effort would necessitate an unduly heavy axle load, with consequent increased capital and maintenance costs, much ingenuity is being expended in devising means of traction which will exert the necessary tractive force without any increase in

the weight of the track. Some of the schemes proposed aim at simple methods of gripping the track rail or a central rail but these have yet to be tested in commercial practice.

An alternative system, known as the Roadrail, has been in operation in Uganda on a commercial scale for some three years and has, therefore, reached a stage when it may usefully be brought to the notice of the Association. In this system the driving wheels of the tractor run on a road surface on either side of a 60 centimetre (2 foot) rail track. The front axle is mounted on a bogie and this bogie and in some cases also a trailing bogie of the tractor run on the rail track. The trains consist of normal 60 centimetre rolling stock. The advantages claimed are that, owing to the increased adhesion of the road wheels, the required draw-bar pull is obtained with a much lighter tractor while the advantage of the low resistance of rail traction is still retained. A light rail track can be used and surface lines can be laid at far steeper grades than can be contemplated with a normal railway. About 28 miles of roadrail have been laid in Uganda with a ruling gradient of 1 in 25, except for a short length of 1 in 20, and minimum curves of 50 feet radius which, however, it has been found desirable to ease. An advantage of the system was the possibility of adapting the ordinary road lorry at very short notice to run on the roadrail and *vice versa*, by merely supporting the front axle on a 60 centimetre bogie. It was perhaps unfortunate, therefore, that two special tractors were constructed for the purpose, being the first of their kind. Trouble and expense had to be incurred locally in remedying defects in engines and chassis. These original tractors have two 25 H. P. four-cylinder, internal combustion engines in parallel; the wheel base is 9 feet : total weight 5 tons, 2 cwt., of which 1 ton, 7 cwt. is on the front axle and therefore carried by the leading bogie. The driving wheels are shod with twin solid rubber tyres and have an overall diameter of 4 ft. 11 in. In favourable conditions these tractors will normally haul five trucks each loaded with 3 1/2 tons, *i. e.*, a total net load of 17 1/2 tons and a gross load of over 27 tons on the maximum grade of 1 in 25. In bad weather when the wheel tracks had been softened by rainfall the net load was 11 tons. In favourable conditions a converted 32 H. P. « Albion » lorry normally hauled a net load of 7 tons and a gross load of 10 tons, 17 cwt. A specially designed tractor which is not used to carry a load itself has the advantage of a constant weight on the drivers, adjusted to utilise the maximum tractive effort of the engine. The most serious disadvantage of the system is undoubtedly the road track which must be solidly constructed to stand the traffic in wet weather. Consequently the availability of ballast is a *sine qua non*.

It is evident that the tractors as described cannot be reversed, as there is nothing to steer them and the latest development has been the construction of a special tractor with a trailing as well as a leading bogie. These tractors are driven by Sentinel steam engines and are specially designed to eliminate the defects of the original tractors. They are reversible and the second bogie should reduce the chances of skidding. The bogies are pivoted on ball and socket bearings under a separate frame which also carries the water tank at one end. Hinged to this frame at the other end is the main chassis of the tractor, the free end of which is guided by side rollers

on the outer sides of the tank. In this way it is possible for one of the road wheels to be tilted up 1 foot above the other and for either the road wheels or the bogies to run 1 foot above the level of the other without affecting the working of the tractor.

The original motors had a tendency, eliminated in the later patterns, to « rear » when the clutch is re-engaged after changing gear. This lifts the cross-frame off the fore carriage bogie or lifts the bogie itself off the rails and causes derailments, notwithstanding that trains are usually made up with one truck in front of the tractor. The new steam tractors are designed to give 40 to 50 normal H. P. but will develop more power when required for short periods. The working boiler pressure is 230 lb. per square inch. The fuel used is coal but it has been proposed to design the fire door and grate to allow of wood fuel or cotton seed being burnt. The total weight is 8 1/2 tons and cost, f. o. b. £1 925 each. The model as at present constructed weighs 8 tons of which 4 tons is on the driving axle and 2 tons on each bogie. The tractive effort is 5 600 lb. cost f. o. b. £1 700. It is claimed that the tractor will haul a working load of 25 tons gross up a grade of 1 in 13 and that a test load of 35 tons was so hauled on the line constructed at the Wembley Exhibition. The original petrol tractors were found to be too complicated for natives to drive, though they are employed on the converted Albion lorry, and it is hoped to employ them on the new steam tractors.

As a result of a careful study of the conditions in East Africa, the opinion has been expressed, contrary to the claims of the company, that the cost, both of construction and operation of a roadrail, with a 4 % ruling grade, is somewhat higher than that of a 60 centimetre light railway on a 3 % grade. It is only fair to remember, however, that the system is in its infancy and no reports are yet to hand as to the working locally of the new tractors.

The system is now being fairly extensively tried in India where the preliminary experiments have been favorably reported on.

Among the exhibits at Wembley were 60 H. P. and 80 H. P. petrol tractors designed for the roadrail but capable of being used as road tractors. It should be mentioned that with the single bogie it is necessary to couple the train by a long rod to the leading bogie. Also that in all the vehicles referred to above chain drive is employed.

SUMMARY.

Rail motor traction.

1. — In Great Britain the most likely field for rail motor cars is to supplement steam passenger services on main lines where a greater frequency is required than would be justified with a steam train service. The advantage of rail motor cars has not yet been generally established in practice.

2. — In the other countries reported on, on lines with a very light traffic the advantage of rail motor cars for passenger service is being clearly established in an increasing number of cases. Further information in these cases as to the traffic conditions and as to the shunting and hauling of goods traffic would be of value.

3. — The normal development of this mode of traction is, firstly, the use of light petrol cars adapted from road vehicles with standard engines and chassis. This is followed by cautious development with larger cars while still adhering as closely as practicable to proved types of engine.

4. — Light-Petrol rail motor cars are inherently ill-adapted to hauling trailers. The adoption of electro-pneumatic control, if successful, will help to solve the question of strengthening trains and widen the field of use for these rail motors.

5. — Rail motor traction has not been used to convey goods traffic. The development of an internal combustion locomotive to enable light traffic to be handled without transhipment has been advocated.

Narrow gauge traction.

6. — Ordinary steam practice is the rule on narrow gauge light railways.

7. — On flat grades in districts where there is risk of fire, bad water for locomotives or where the traffic is intermittent, petrol tractors have a useful field.

8. — On light feeder lines, such as estate railways, the need for simplicity and the possibility of slow running point to a single cylinder horizontal oil engine with rod couplings as an effective solution.

Special traction.

9. — The problem of feeder lines for light traffic over difficult country requires special devices in order to reduce the weight of the tractor for a given adhesion.

APPENDICES.

Appendix A.

Detailed list of questions relating to question XV.

Note. — The term « Light railways » is taken to denote railways which, on account of the lightness of the traffic, have been constructed or are worked under conditions which constitute a derogation from ordinary main lines practice in the same or similar countries.

Kindly omit questions marked (*) in the case of rail motor cars which are dealt with in section *B* of this list of questions.

LIST OF QUESTIONS.

A. — **Special systems of traction for light railways.**

1. — What is the mileage of light railway operated ?
What is the gauge ?

2. — Is the light railway a feeder line to a main line, or an independent line ?

3. — What are the ruling and maximum grades and curves ?

4. — What is the weight of rail and the number of sleepers per mile ?

5. — What is the average number of tons per month conveyed in each direction ?

6. — What is the average number of passengers per month conveyed in each direction ?

7. — How many : *a*) passenger; *b*) mixed; *c*) goods trains are run per day in each direction ?

8. — What are the special features of your traction problem ?

9*. — What system of traction have you adopted ? Please give detailed description with drawings and photographs of the different types of steam, electric, and other locomotives in use. In the case of electric locomotive, please give particulars of the power plant.

10*. — What fuel do you use ?
What is the consumption of fuel or energy per engine mile ?

11*. — What number of locomotives have you of each type ?

a) In service;
b) Awaiting repairs;
c) Under repairs.

12*. — What is the gross load, and the net tons or number of passengers which can be handled by each type ?

13*. — What is the usual composition of: *a*) passenger; *b*) mixed; *c*) goods trains, for each type of loco ?

14*. — What does the train staff consist of ? Do they collect charges ?

15*. — What are the maximum speeds attained in practice ? Are they limited by the condition of the track ?

16*. — What type of brake is used ?

17*. — At what dates were the various types of locos put into use ?

18*. — What is the cost per engine mile for each type, showing separately :

Personnel;
Fuel or energy;
Running stores;
Maintenance.

19*. — Do you hope to reduce this cost, if so, how ?

20*. — What are the advantages and disadvantages for your purposes of the different types employed ?

21*. — Have you considered or tried the use of other forms of traction, if so, what were the reasons for not adopting them, or for discontinuing them ? Please give details of any type of traction which has been tried and adandoned.

B. — Rail motor traction.

(Excluding electric cars fed from conductors along the line.)

22. — What is the mileage of line on which rail motor traction is operated ?

What is the gauge ?

23. — What are the ruling and maximum grades and curves ?

24. — What is the weight of rail and the number of sleepers per mile ?

25. — What is the average number of tons per month conveyed in each direction ?

26. — What is the average number of passengers per month conveyed in each direction ?

27. — What are the special features of your traction problem ?

Is rail motor traction the only form of traction employed ?

If not, what is the extent and nature of the traffic looked after by the rail motors ?

28. — Please give detailed description with drawings and photographs, stating weights, etc., of the different types of rail motor cars employed.

Give particulars of the arrangement of passenger accommodation, heating in winter, artificial lighting, etc.

What are the driving arrangements ?

Are they at one or both ends ?

What space is reserved for parcels ?

Give a detailed description of the mechanism.

What is the purchase prise, stating date of purchase ?

In the case of electric cars, please give particulars of the power plant.

29. — What fuel do you use ?

What is the average consumption of fuel or energy per motor vehicle mile ?

30. — What number of rail motor cars have you of each type ?

a) In service;

b) Awaiting repairs;

c) Under repairs.

31. — What is the carrying capacity per car of passengers, parcels, and luggage ?

32. — Do you use trailers ? If so, what is the maximum number of trailers hauled with one motor car ?

What is the tare weight and the maximum net load (in tons if goods vehicle, in number of passengers, if passenger vehicle) of each trailer ?

33. — How many employees are required on a rail motor car for all purposes ?

Does the personnel on the car collect the fares ?

How are the duties organised ?

34. — What are the maximum speeds attained in practice ?

35. — What type of brake is used ?

36. — At what dates were the different types of rail motor cars put into use on your line ?

37. — What is the cost per car mile of each type, showing separately :

Personnel;

Fuel or energy;

Running stores;

Maintenance.

38. — Do you hope to reduce this cost ? If so, how ?

39. — What are the advantages and disadvantages for your purposes of the use of rail motor cars ?

Do you propose to extend their use ?

40. — What are the comparative advantages and disadvantages of the different types of rail motor cars in use ?

41. — Have you considered or tried the use of other forms of traction for the traffic now handled by the rail motor cars ?

If so, what were the reasons for not adopting them or for discontinuing them ?

Please give details of any types of rail motor cars which have been tried and abandoned.

Appendix B.

Rail motor vehicles on British railways.

RAILWAY.	Type of vehicle.	Number.	Seats.
London Midland & Scottish	Steam.	28	1 461
Great Western	Steam.	53	3 023
London & North Eastern	Steam.	6	296
	Petrol.	2	66
	Petrol power (shunting).	1	...
	Petrol electric.	3	146
Southern	Steam.	9	496
	Petrol.	1	15

Appendix C.

Particulars o

NAME OF RAILWAY.	Length of railway.	Gauge.	Maximum grade.	Makers.	Type of engine.	Number of cylinder.
Rhodesia Railway	...	3' 6"	...	Clayton Wagons, Ltd.	Petrol (1).	4
Barbadoes Railway	...	2' 6"	1/28	Drewry Car Co., Ltd.	Petrol (2).	4
Kalka Simla (India).	60	2' 6"	1/33	Drewry Car Co., Ltd.	Petrol (3).	6
Chesapeake Western Railroad (U. S. A.).	40	4' 8 1/2"	...	J. G. Brill & Co. (U. S. A.).	Petrol (4).	...
New York, New Haven & Hartford Railway (U. S. A.).	...	4' 8 1/2"	...	...	Petrol (5).	4
South India Railway	46	Metre.	1/127	Motor Rail & Tram Car Co., Ltd.	Petrol (6).	4
New South Wales Railway. (No. 1 car).	36	4' 8 1/2"	1/50	Converted Moreland Road lorry.	Petrol (7).	4
New South Wales Railway. (No. 2 car).	63	4' 8 1/2"	1/60	Locally designed.	Petrol reversible (8).	6
New South Wales Railway. (Nos. 3-7 cars).	114 112 43 17	4' 8 1/2"	1/50 to 1/300	Locally.	Thornycroft Marine Type benzine.	6
Jersey Railways and Tramway Company.	7 3/4	3' 6"	1/40	Sentinel Wagon Works, Ltd. Cammel Laird, Ltd.	Steam (9).	2 double acting.

(1) For service in tropical climate at varying altitudes up to 5 000 feet. Fuel capacity 13 gallons.
(2) Can be used as non-engine carriage on steam train. Fuel capacity 60 gallons.
(3) 2-4-2. Reduced time of journey from 6 hours to 3 1/2 hours.
(4) Omnibus body. Arrangements for strap hanging. Any type of chassis can be converted.
(5) 2-1-0.
(6) Cost £1 374; pre-war price.

or coaches.

Appendix C.

roke.	Engine speeds.	H. P.	Drive.	Number of gear speeds.	Speed of vehicle, miles per hour.	Fuel consumption.	Length overall.
mm.	1 000	25	Chain.	3	9.55 19.8 44.6	19 miles per gallon.	15′ 1″
6″	1 000	60/65	Chain.	3	4 10 15	...	...
5	...	40/45	...	...	Average, 18	...	...
...	...	45	...	4 each way.	Maximum, 30 m. p. h.	14 miles per gallon.	37′ 10″ (car, 21′ 11″)
6″	...	40/60	...	4 each way.	35 on level; 20 on 1/150	...	27′ 10″
...	1 000 1 500	40 52	Worm drive.	3 each way.	Average, 15	9 miles per gallon.	40′ 0″
...	...	50	...	...	...	...	...
6	1 000 1 600	105 160	Overhead worm gear to 2 axles of 1 bogie.	3 epicyclic.	30	...	...
...	1 400	72	...	4 each way.	35	...	44′ 8″ 40′ over body.
9″	240	...	Chain.	...	Average, 16.75; maximum, 25	5.37 lb. coal per mile running and standing. 6.27 including lighting up. Water 3.89 gallons per mile.	56′ 6″

(7) Very successful.
(8) Weight due to use of standard body.
(9) Boiler vertical type with cross water tubes. Central top feed for fuel. Superheater. Working pressure 230 lb. per are inch. Superheat 100° F. 20-22 lb. steam per B. H. P. Independent poppet valves, worked by cam shafts, can be held n for coasting. Claimed that these cars could run on a 30 lb. rail. They replace trains weighing 56 tons gross seating persons. Average saving in ton miles 73 %. Saving of fuel 72 % = £600 per annum per coach. Weight per unit of seating acity 0.27 tons.

Appendix C. (Continued.) **Particulars of**

NAME OF RAILWAY.	Width overall.	Height overall.	Wheel base.	Diameter of wheels.	Tare weight.	Numb of passeng
Rhodesia Railway	6′ 10′	7′ 7″	7′ 9″	2′ 6″	3 t. 5 cwt.	6 inclu drive
Barbadoes Railway	...	...	...	2′	...	9 : 1st c 35 : 3rd c
Kalka Simla (India).	...	...	...	...	...	16 to
Chesapeake Western Railroad (U. S. A.)	7′ 10 1/2″	9′ 6″	Bogie, 3′; rear axle to bogie p n, 16′ 6″	Bogie, 20″	5 1/2 tons.	31
New York, New Haven & Hartford Railway (U. S. A.). . .	9′ (inside).	10′ 5″	...	Driving, 40″ bogie, 20″	10 t. 5 cwt.	35
South India Railway	8′ 5″	10′ 6″	Bogie 5′; bogie centres, 22′	...	11 t. 3 cwt.	70
New South Wales Railway. (No. 1 car).	...	...	Bogie, 4′ 3″	Drivers, 42 1/2″	7 t. 16 cwt. 2 qr.	33
New South Wales Railway. (No. 2 car).	...	...	...	...	26 t. 7 ctw. 2 qr.	55
New South Wales Railway. (Nos. 3-7)	9′ 8″	11′ 6 1/2″	Bogie, 5′; bogie centres, 28′	Drivers 32″ trailers 25″	11 tons.	45
Jersey Railways and Tramway Company.	8′	11′	Driving bogie, 7′; other bogie, 5′	...	15 tons.	56

r coaches.

Appendix C. (Continued.)

ggage and rcels.	Control — One or both ends.	Trailer.	Number of cars in use.	Date of construction.	Type of brake.	Running staff.	Running cost per mile.
...	Both.	No.	2	1924	Internal expanding; front wheels hand lever, back wheels foot pedal.	1	...
...	...	Yes, one.	...	1924	Westinghouse.	...	...
...	...	...	2	1914 1921	Hand screw. Also drum brake on countershaft.	...	...
box hind.	One.	Yes, one. Tare, 3 tons; 35 passengers.	...	1921	Hand and foot.	1	...
00 lb.	...	...	3	1921	Westinghouse.	...	...
ton.	Both.	No.	2	1915	Hand.	1 driver. 1 guard.	4.41 d.
...	One.	Yes, for cream traffic.	1	1919	Hand wheel on bogie. Foot on rear wheels.	...	...
...	Both.	No.	1	1922	Westinghouse.	...	...
ons or ssengers	Both.	No.	5	1923-1924	Westinghouse.	...	...
...	Both can be provided.	Yes.	1 1	1923 1924	Hand and steam.	...	4 d. to 7 d. including trailer.

Appendix D.

Narrow gauge feeder lines

NAME OF RAILWAY.	Gauge.	Length.	Grades.	Rails pounds per yard.	Average tons per month.	Average passengers per month.	Ty of locomo
South India Railway.	Metre.	221	1/200 (1)	41 1/4	16 748	263 184	2-8
	2' 6"	99	1/67	30	16 000 (2) 32 000 (2)	18 000 39 000	..
Bengal Nagpur Railway. . . .	2' 6"	629	1/80 1/100	31 to 40	60 000 to 70 000	215 000	2-8 2-8 4-6
Great Indian Peninsular . . .	2' 6"	201	...	...	12 000	115 700	2-8-2 t 2-8-4
South African Railways. . . .	2'	92	1/60	35 to 47	...	...	2-6 4-6

(1) Tanjore District Board Railway : 1 rupee taken as 17.5 pence.

s per engine mile. (STEAM TRACTION.)

Appendix D.

Veight of motives working rder.	Coal per mile pounds.	Gross load of train.	Maximum speed, miles per hour.	Composition of trains (maximum).	Cost per engine mile (pence).				
					Personnel.	Fuel.	Running stores.	Maintenance.	Total.
5 tons. 2 tons.	50	160 to 180 tons.	25 to 30	7 to 8 bogie carriages.	2.83	11.03	0.40	2.60	16.86
...	35	...	20	...	2.47	8.34	0.30	2.44	13.55
					2.47	8.34	0.40	0.82	12.03
...	71	1/84 150 to 250 tons. 1/100 300 to 350 tons.	30	13.16 vehicles. 18-22 vehicles.	2.08	3.67	0.35	3.65	9.75
...	70	400	17 to 20	20 vehicles.	...	...	...	...	47.25
1/2 tons. 20 tons.	52	T. F. 9 036 lb.	15 goods, (18.3 for passengers)	60 axles.	6.81	2.00	0.31	0.16	9.28

(2) Refers to different sections.

Appendix E.

Details of principal types of Light Railway Engines used on the Western Front.

	Hudson 0-6-0 Well Tank.	Hunslet. 4-6-0 Side Tank.	Baldwin. 4-6-0 Side Tank.	Barclay. 0-6-0 Well Tank.	American. 2-6-2 Side Tank.
Cylinders :					
Diameter	0′ 6 1/2″	0′ 9 1/2″	0′ 9″	0′ 6 3/4″	0′ 9″
Stroke	1′ 0″	1′ 0″	1′ 0″	0′ 10 3/4″	1′ 2″
Length of boiler	5′ 6″	5′ 0″	7′ 0″	5′ 10″	...
Diameter of boiler	2′ 1″	2′ 9″	2′ 9″	2′ 2 3/4″	2′ 8″
— of bogie wheels	...	1′ 6 1/2″	1′ 4″	...	1′ 4″
— of coupled wheels	1′ 11″	2′ 0″	1′ 11 1/2″	1′ 10″	2′ 3″
Coupled wheelbase	4′ 2″	5′ 6″	5′ 10″	4′ 4″	5′ 6″
Total wheelbase	4′ 2″	13′ 0″	12′ 4″	4′ 4″	15′ 9″
Heating surface :					
Tubes, in square feet	108.5	168	231	111	...
Firebox, in square feet	17.5	37	23.5	20	...
Total, in square feet	126	205	254.5	131	272
Grate area, in square feet	3.25	3.95	5.6	3.5	5.5
Capacity of tank, in gallons	110	375	396	110	396
— of bunkers, in cwt.	3.5	15	15.7	3.5	15
Working pressure, in lb. per square inch	150	160	178	160	175
Tractive force, in lb.	2 970	5 415 (at 75 % b.p.)	5 510	...	...
Valve gear	Walschaerts.	Walschaerts.	Walschaerts	Walschaerts.	Walschaerts.
Brake	Hand.	Steam and hand.	Steam and hand.	Hand.	Steam and hand.
Firebox	Copper.	Copper. Belpaire type.	Copper.	Copper. Belpaire type.	Copper.
Tubes	Steel : 45	Brass : 86	Brass : 83	Brass : 45	Brass : 54
Width overall	5′ 8″	6′ 3 1/2″	6′ 11″	5′ 5 1/4″	6′ 9″
Height overall	8′ 8 3/4″	8′ 11 1/2″	9′ 3 1/4″	8′ 4 1/4″	9′ 0″
Length over buffers	15′ 5 1/4″	19′ 10 3/4″	19′ 6 1/8″	14′ 2 7/8″	...
Weight :					
Empty, in tons	5.775	10.9	11.04	5.9	...
In working order, in tons	6.8875	14.05	14.7	7.0	...
Maximum weight :					
On a pair of wheels, in tons	2.3875	3.5	3.46	...	3.5
Per foot of wheelbase, in tons	1.653	1.08	1.14	...	...
Per foot run over buffers, in tons	0.446	0.708	...	...	...
On coupled wheels, in tons	6.887	10.5	10.38	...	...
Tubes : External diameter and length	1 5/8″ × 5′ 8″	1 1/2″ × 5′ 0 1/8″	1 1/2″ × 7′ 2″	1 5/8″ × 6′ 0″	2″ × 8′ 5″

[621 .133 & 621 .137.1]

REPORT No. 1

(America)

ON THE QUESTION OF REDUCTION OF THE COST OF TRACTION : FUEL AND ITS COMBUSTION (SUBJECT IV-A FOR DISCUSSION AT THE TENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION), (1)

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This report on the question of fuel and its combustion will be confined to the consideration of the question as it applies to conditions and practices effective on the American railroads and particularly the railroads of the United States of America.

Choice of locomotive fuel.

General considerations governing choice.

Neglecting considerations involving traffic and revenue and viewing only those involved in the operation of the railroad, the choice of locomotive fuel is governed by two main factors :

1° Availability in adequate quantity;

2° Total cost per unit of power output or of transportation produced, including the effect upon locomotive capacity, interest on locomotive cost and depreciation, efficiency of the fuel, cost of maintenance of locomotives and cost of fueling and preparing locomotives for service.

The problem of selecting the most suitable fuel for locomotive operation is, in the case of many railroads, not simple, because many economic factors, such as price, assured source of supply and distribution, have to be considered.

The physical qualities of the fuel effecting the efficiency of handling and its action under the conditions of its combustion have a bearing of great moment and the heat content per pound of fuel as fired is a consideration of increasing importance as the limits of permissible size of grate area and tender capacity, are approached in locomotive design.

Coal.

1° *Availability in adequate quantity.*

The supremacy of bituminous coal as fuel for the locomotives of the world is based upon its general wide distribution in deposits available for ready production in quantity adequate for present and probable future requirements in practicably every section of every country.

It is, of course, the common practice of railroads to use the coal produced in the most convenient localities with reference

(1) This question runs as follows : « Fuel and its combution : *a*) Choice of fuel : coal, mixing of coals, peat, oil fuel, pulverised fuel, mixing of solid and liquid fuels (colloidal fuel); — *b*) Apparatus for the combustion of solid fuel (rocking-grates, etc.), liquid and pulverised fuels; — *c*) Mechanical stokers; — *d*) Smoke consumption. Spark arresters. »

to haul to the line and distribution to fueling stations, this practice being subject to modification dependent upon relative costs and qualities of competitive coals. Roads which originate coal traffic for obvious reasons use coal produced upon their own lines, while lines located remotely from producing coal measures have consistently more ground for choice between competing producers.

During the calendar year 1923 the railroads of the United States consumed approximately 130 000 000 tons of coal. The closest competitor as locomotive fuel was fuel oil, with consumption of about 54 000 000 barrels, equivalent roughly to 15 000 000 tons of coal, so that practically 90 % of the locomotive fuel of this country was coal.

The former practice of some half dozen railroads operating in territory adjacent to the anthracite fields of using anthracite coal for locomotive fuel has within the past ten years, been abandoned, because of the steadily mounting cost of that variety of coal on account of the limited supply available and the demand for it as fuel for heating purposes in residences and buildings in cities along the Atlantic seaboard. The coal at present used as locomotive fuel in this country is almost exclusively bituminous coal of high rank, with heat content of 13 000 to 15 000 British thermal units per pound, varying in volatile content from about 15 % to 40 %. The abundant supply of the high rank coal, the comparatively favorable cost of its production, transportation and distribution and the relatively higher costs incident to the processes so far developed for modifying the lower rank fuels have prevented the commercial development in this country of processes for utilizing the resources of low rank fuels upon any scale at all comparable to that obtaining in many European countries, where as a general rule these controlling factors have operated in reverse effect.

Coal of a quality and in quantity that would be regarded as important by most other nations is found in all but 13 states of the United States and commercial mines are being operated in 29 states. However, 93 % of the bituminous coal comes from three major areas : The Appalachian region extending from Pennsylvania to Alabama, the greatest storehouse of high rank coal in the world; the Eastern Interior region, comprising Illinois, Indiana and Western Kentucky; and the Western Interior region extending from Iowa to Arkansas and Oklahoma.

The output of bituminous coal is consumed in approximately the following percentages :

Railroads	28 %
Industries	25 %
Coking	15 %
Domestic heating	10 %
Iron and steel	7 %
Public utilities	7 %
Export	4 %
Mines	2 %
Bunkering of Ships	2 %

The availability of coal in adequate quantity and at comparatively low cost in these extensive sections of this country explains its practically universal use as locomotive fuel except in the remote sections involving long hauls, which as it happens are near to abundant supplies of crude oil.

2° *Total cost per unit of power output or of transportation produced.*

In considering the fuel cost per unit of power output or per unit of transportation produced, it is necessary to take into account, in addition to the sales price, and the cost of haul, the effect it has upon lo-

comotive capacity and consequently upon the factors involved in the investment in locomotives as well as the effect upon expense of maintenance; handling of the locomotives in the engine terminals and preparation of the locomotives for road service after the completion of previous trips.

The sales price and the cost of haul to consumption points is of course, primarily dependent upon the first general consideration governing the choice of the fuel, *i. e.* the availability of an adequate supply and the distance of the source of supply from consumption points; and is secondarily dependent upon the cost of production and the « supply and demand » factor in power consuming industry in general. These factors are strongly favorable to the use of the high rank coals of this country for our locomotive fuel in every section except the few where the conditions surrounding the production of fuel oil are particularly favorable.

The high rank coals being available at favorable cost of delivery to consumption points it follows that the effect upon locomotive capacity as compared with that of fuels of higher heat content per pound is not to a prohibitive extent unfavourable such as might be the case if lower rank coals only were available. Under the existing conditions selection may be freely made from coals exhibiting a wide variety of characteristics as to proximate analysis, action in the firebox under varying conditions of combustion, action of the ash affecting the cleaning of fires and the effect of the fuel upon the expense of maintaining the boiler.

Mixing of coals.

The practice, more or less common in European countries, of mixing a proportion of low grade or low rank coal with coal of better grade or higher rank in order to compensate to some extent for the high cost of the latter and its relative scarcity, at the same time exercising care to insure that the resultant fuel retains sufficient of the high rank characteristics to give satisfactory results in service, is not followed to an appreciable extent in the United States because of the low average cost of the high rank coals available in adequate quantity and the slight margin of saving in cost after due allowance for the expense of the mixing operation.

Such mixing as is practiced is largely unpremeditated and incidental to the handling of coals of the same or closely identical ranks but from various mines through the same disbursing station or ground storage yard, or, as is occasionally the case, mixing is practiced to reduce the volatile content of the predominant fuel used in a zone where restrictions on the emission of smoke may be in effect. The smaller grades of anthracite for which only a limited market exists, are mixed to a limited extent, in such zones in proximity to the producing region, with the coals of higher volatile content in general use for locomotive fuel.

Peat.

The abundance of high rank coal deposits has forestalled the general use of lower rank fuels on locomotives in this country. The following extracts from reports to the International Railway Fuel Association indicate the situation in this respect.

Fuels such as peat and lignite have not been successfully used generally in the raw state for steam generation and the processes so far developed which make possible the economical combustion of fuels of low heat content and of

such physical structure as unfit them for use in the ordinary firebox or furnace, are highly complicated because of the chemical and physical considerations involved in changing the form and structure of the fuel and increasing the heat content per pound of the fuel as fired.

Deposits in this country, approximately established amounting to over ten billion tons, occur in the states bordering the Great Lakes and along the Atlantic and Gulf Coasts. Extensive deposits also occur in Canada; in the provinces of Ontario and Quebec peat has been produced for fifty years. In the United States, New-England has been the most productive. Considerable money has been spent in developing the production of peat fuel along commercial lines, but the efforts have failed because of the great quantity of better fuel available. It is not practicable to ship peat fuel to distances requiring movement by rail. The producing season is limited by freezing temperature.

The total coal resources of the United States are estimated at about 3 500 billion short tons, of which about 33 % is lignite. About 91 % of the lignite occurs in the Dakotas and Eastern Montana, 3 % in Texas, 1 % in Alaska and smaller quantities in several other western and southern states. Due to the difficulties in the use of raw lignite, among other causes, over two million tons of bituminous coal are shipped each year an average distance of 1 000 miles into territory tributary to the Dakota lignite deposits. Lignite is brown and dull in color, woody in texture, and non-coking. It is high in percentage of moisture, which is readily given off. Spontaneous combustion is easily started, making it unsafe to store. It crumbles in the fire and gives a high percentage of loss through the grates.

Lignite may be used in the following forms :

Dried lignite. — This form of the fuel crushes so easily that the loss through the grates is too high for economical results when fired by hand. It is a more satisfactory fuel when fired mechanically.

Dried lignite briquettes. — This form of lignite fuel is made by crushing, drying and pressing without binder if practicable or with binder if the character of the fuel is such as to require it. The briquettes resist weathering much better than raw lignite, bear handling and give increased efficiency as boiler fuel. Briquettes made without binder do not hold together in the firebox nor resist weathering as well as those made with binder

The substitution of these low rank coals for bituminous fuel introduces, in addition to the difficulties already mentioned, a number of problems of operation. Because of the generally lower heat value and the difficulty of realizing this value in the fire-box it is obvious that a much large quantity of coal must be burned in a given time in order to develop the required horsepower. For this reason the grate area must be greater — one authority says 50 % greater — than would be required for good bituminous coal. The disintegrating action of the heat further complicates matters by increasing the resistance of the fuel bed to the flow of air through it. High drafts are necessary in order to overcome this resistance and maintain the required rates of combustion and to get them the exhaust pressures must be increased to such an extent that the efficiency of the locomotive is reduced 5 to 10 % thereby.

The results of these tests show that the better of these low rank fuels can be used, and, in fact, they are today being

used ovec those divisions of the roads where length of haul of bituminous coal makes it too expensive or otherwise inadvisable to use the latter fuel. The use of oil, however, has so many advantages that it will usually displace any solid fuel whenever the cost of oil is low enough to keep the fuel item in operating expense near to what it would be with coal used on the road. This substitution of oil for coal has to a considerable extent taken place in the Wyoming territory since the development of the oil fields in that state.

As to the future use of these coals, there seems to be no question but that they will be used in increasing quantities. There is doubtless much to learn yet relative to the proper grate area to heating surface ratios that will give best results with different coals. Some of the lines which are today using this sub-bituminous fuel are using it on the same engines that at other times burn bituminous coal. It is possible that it may sometime be found of sufficient advantage to build all the locomotives which are to be fired with the lower grade fuels with special reference to obtaining the best results from them.

Another factor, and an important one, in determining the extent of the future use of the low rank coals is the rapidity with which the country, and especially these parts in which are deposits of these coals, develops. In many districts where sub-bituminous coals are mined there is little or no market for slack, but this finer size coal must be screened out of the mine run fuel in order to prepare it for the existing markets. With the growth of local industries will come more of a demand for the slack, which will, in turn, decrease the cost of locomotive coal at the mine. This will, of course, widen the area within which it will be uneconomical to use bituminous.

The probability of a marked increase in the use of the true lignites in the near future is believed to be not great. The present undeveloped condition of the parts of the country in which the lignites are found, their low heating value, and the availability of the better sub-bituminous coals are all factors that will check the increased use of lignitic coals for steaming, and particularly for locomotive purposes.

Considerable experimental work has been done to develop the possibilities of processes for utilizing these fuels in carbonized forms with recovery of the by-products. Since this work has not advanced to the extent of affording a fuel which can compete with the high rank coals available in either quantity or cost, no detail reference thereto appears to be desirable in the present discussion.

Pulverized fuel.

The application of equipment for the burning of pulverized fuel on locomotives was first attempted in this country in 1914 and since that time applications to one or more locomotives have been made on four other railroads and extensive experiments and trial have been made using a great variety of fuels and combinations of fuels of high and low rank with various modifications of the arrangement of the coal burning equipment, and of the conditions in general under which the trials were conducted.

The International Railway Fuel Association has had a standing committee to report on the subject to each annual convention of the Association from 1915 to 1921 inclusive, and it is considered that the conclusions of this committee embody a fair appraisal of the existing status of the developments in this direction. It was found that under the conditions of

the limited combustion space available in the locomotive firebox of conventional design adequate means for disposing of the slag resulting from the combustion of pulverized fuel have not been developed, the slag quickly accumulates on the flue sheet and shuts off the draft, and so far the results of attempts to remedy this condition have been so discouraging that active experiments by railroads have been practically suspended. The Committee in 1920 reported as follows :

The 1919 report of the Standing Committe on Pulverized Fuel, called particular attention to the necessity of obtaining reliable statistics on the comparative costs of producing power with pulverized coal and other standard methods of coal burning in order that the economical phase of the subject, on which there exists much doubt, may be cleared up.

It was decided therefore, in view of the fact that it has been pretty conclusively established that coal can be successfully burned in pulverized form, that the 1920 committee would confine its efforts to collecting reliable comparative cost data.

Diligent inquiry during the year from many sources suggested has failed to produce any comparative cost data whatever. One application for burning powdered coal on a locomotive and a considerable number of stationary plant installations were reported. No information was obtainable on the locomotive application. Some of the stationary plant operators report successful results with pulverized coal, and state they are operating more economically with it than they have previously with oil or with ordinary methods of coal burning. None, however, have made comparative tests, and are unable to give exact figures.

The committee regrets that it has through resources heretofore available been unable to obtain for the Association the accurate cost data which it believes necessary to establish the standing of pulverized coal as an improved and more economical method of power production. Until such data is obtainable there is little that can be done by the committee.

The Committee in 1921 reported in part as follows :

The progress of the art of burning pulverized coal by railroads on their locomotives or in stationary plants the past year has, on account of well understood economic and other conditions, been practically nil, no new installations having been made.

Some few tests have been made. One of these which is of some interest was a test made on Lehigh Valley locomotive No. 1360 between Easton and Lehigton, Pennsylvania, to determine the practicability of burning pulverized North Dakota lignite containing fifteen per cent moisture and Red Lodge sludge (Montana sub-bituminous coal) without serious honeycomb formation or unusual disintegration of brick work.

The results were successful with the exception of the honeycomb formation which with either coal developed rapidly on the back flue sheet when the locomotive was worked hard and seriously hampered operation. Your Committee suggests that this honeycomb formation be not taken too seriously and believes that with proper research and engineering work to determine the coal characteristics and to develop proper design of boiler and firebox with particular reference to combustion area and also to drafting, that this problem can be solved. In connection with drafting the Committee has in mind the elimination of pulsating draft and correctly determined air supply.

Oil fuel.

As previously stated oil fuel is the only fuel for locomotives aside from coal which is used in this country in significant quantity. On the score of availability in adequate quantity and at an average cost which is not prohibitive, oil fuel outranks all competitors in some extensive sections of the United States and competes on even terms in others. The flush production of asphaltum oil in the state of California on the Pacific Coast where deposits of high rank coals are entirely wanting and deposits of low rank coals are rare, makes the use of oil for locomotives as well as in general industry and steam generation mandatory throughout that and a number of adjacent states. In similar manner the developments of oil production in the Gulf Coast sections of the states of Texas and Louisiana and in interior sections such as the state of Oklahoma presents the problem of choice between coal and oil and results in a situation in which lines closely adjacent may be found, some using oil fuel and others using coal, or on the same line, some divisions using coal while other divisions use oil fuel.

In the case of a railroad located on the border line between coal producing and oil producing territory the choice may and frequently does rest alternately on oil and coal, fluctuating with the varying costs of the competing fuels.

As an example of this condition the position of the Atchison, Topeka & Santa Fe Railroad may be cited and in illustration of the method followed in arriving at the choice of fuel, the following quotation is made from a paper entitled « Oil burning practice on locomotives on the Atchison, Topeka & Santa Fe Railroad System » by Walter Bohnstengel, Assistant Engineer Tests, published in the Proceedings International Railway Fuel Association 1920 :

Consideration of oil burning. — The essential features in preparing to burn oil for locomotive fuel is the availability extent of supply, and relative value of the oil, not at the well, but at the point of consumption.

The cost of changing a locomotive from coal to oil burning depends largely on the size of the locomotive. Recent figures show that the approximate cost of changing a modern locomotive of Pacific, Mikado or Atlantic type is from $2 400 to $2 500, including the construction of an oil tank, draft pan, petticoat pipe, oil burner piping, fittings, etc. This cost would also include the application and the usual overhead charge. A smaller locomotive, such as the eight and ten wheelers, can be converted at a cost of about $1 800 to $2 000 each.

The use of oil fuel for steam generating purposes in specific localities follows closely the changing tide of oil production to the discovery and exhaustion of deposits, each flush development resulting in a certain degree of displacement of coal for steam making and each material reduction in production forcing consumers back to coal for fuel purposes.

In a paper read at the 1923 Convention of the International Railway Fuel Association Mr. C. E. Beecher, Petroleum Engineer, U. S. Bureau of Mines, summarized the advantages derived from the use of fuel oil in the following language.

Maintenance advantages.

1. — On the basis of theoretical heat units one ton of fuel oil is approximately equivalent to 1.46 tons of coal, but on the basis of actual operation, one ton of fuel oil is more nearly equal to 1.79 tons of coal. Considering these

figures with respect to tonnage hauled it means a saving of 44 %, provided the haul on fuel oil is approximately the same as on coal.

2. — The handling and switching charges at fueling points would be greatly reduced.

3. — The necessity of maintaining separate bunkers for different kinds of coal would be eliminated because fuel oil is practically uniform in character, and all stock could be placed in same tank. Also far less space is required to store a given supply of fuel.

4. — Smoke can be almost entirely eliminated. This is a most desirable feature for locomotives operating in districts where local ordinances require smoke elimination. Many railroads find it necessary to provide special grades of coal, often at great expense, for use in such restricted districts. At some terminals, the use of electric engines has eliminated this difficulty.

5. — Fuel oil does not deteriorate in storage. Its heating value remains the same over long periods of time, and it is possible to store any desired quantity by providing sufficient tankage. On the other hand, it is impractical to store large quantities of coal because of the space required and because many coals deteriorate rapidly and some higher grade coals fire spontaneously. Therefore, the average railroad carries enough coal on hand to last only a short time.

6. — An equal weight of oil can be stored in approximately two-thirds of the space required for coal, and an equal volume of oil has 50 % greater heating value than coal. When space is limited bunker volume is often of great importance and frequently oil can be stored in places which are practically useless for other purposes.

7. — There are no ashes, clinker or dirt to contend with when oil is burned, for it is completely combustible. The services of stokers and ash handlers are not required.

8. — Oil can be handled cheaper and with less effort than coal. A simple pumping unit, pipe lines and tanks take the place of expensive and complicated conveyors, hoists and other elaborate devices commonly used for handling coal.

9. — The cost of shovels, slice bars and other firing tools can be eliminated.

10. — Maintenance charges for an oil burning locomotive are approximately the same as for a coal burner, provided proper refractory materials are used in the fire box and the draft properly regulated.

11. — The time required by the average coal burning locomotive to recoal and remove ashes at terminals and along the line will be saved. At terminals this means a saving of two to three engine house hours.

12. — Overtime wages paid to engine and train crews can be materially reduced because the oil burning locomotive can maintain a more uniform schedule.

Mechanical advantages.

1. — There is no loss of fuel because of the necessity to bank fires. Oil fires can be started almost instantly, and the boiler temperature and pressure increased rapidly.

2. — An oil fire is easily controlled and responds more readily to varying steam demands than a coal fire, because steam can be generated faster. It is possible to maintain a boiler pressure close to the maximum without the frequent opening of the safety valve which always results in a loss of steam and fuel.

3. — Greater evaporative efficiency

can be maintained because less material is deposited on the tubes and other heating surface.

4. — With fuel oil there is no need of opening the fire box door as when firing coal, and opening the fire door never fails to admit a rush of cold air to the sheets and flues.

5. — A smaller per cent of excess air is required, resulting in higher temperatures and a smaller volume of waste gases.

6. — A smaller combustion space is required, thus radiation losses are reduced.

7. — Damage to the machinery and lubricating troubles caused by dust from coal and ashes will be eliminated.

8. — The volume of fuel used can be accurately measured. This is of special importance for compiling data on the performance of engine crews and in making engine tests. The complicated machinery used for weighing coal is unnecessary. The amount of fuel on hand at any given time can be quickly determined.

9. — Flue gas analysis shows that less fuel is lost through the stack.

10. — Cinders, which are a constant source of annoyance and expense, are eliminated.

11. — Longer locomotive runs can be made because much greater heat value in the form of oil can be carried in the same space provided for coal.

Safety advantages.

1. — Unlike coal, oil is not subject to spontaneous combustion. Fire hazard is the chief source of danger and this can be reduced to a minimum by properly constructed and vented tanks. In the process of refining the lighter and more volatile products such as naphta, gasoline and kerosene have been removed, leaving practically nothing in the fuel oil which will volatilize and thus create a fire hazard.

2. — Danger to the employe in handling oil is less than with coal, thus eliminating many personal injury suits.

3. — Fire, hazard along the right-of-way is greatly reduced.

4. — In an oil-burning locomotive the fireman can maintain his seat in the cab and thus be in a position at all times to observe operating signals. For fast trains this additional factor of safety is especially desirable.

Production, consumption and reserves of crude oil in United States.

The advantages in favor of fuel oil are so many that it might appear as though the railroads not using oil-burning locomotives were being inefficiently operated. Such a conclusion however, would not be justified, for there is not sufficient fuel oil produced in this country to operate all the railroads for more than a few months out of each year. If all the railroads now using coal were to substitute fuel oil, 406 000 000 barrels would be required annually, in addition to the 37 000 000 now being used, or a total of approximately 443 000 000 barrels which is equal to almost twice the amount of fuel oil produced last year (1922). It is evident from these figures that fuel oil can not replace coal as a locomotive fuel except to a relatively small extent and that where conditions are most favorable.

Production of crude oil has increased rapidly in this country, especially during the past few years. Consumption has likewise increased, and in 1920 was even greater than production but at present, due to the large flush production being obtained from new fields, such as Smackover in Arkansas; Santa Fe

Springs and Signal Hall in California; Tonkawa in Oklahoma, and others, production is gaining on consumption. This period of overproduction is only temporary. Similar periods have been experienced in the past when the flush production of some large fields has caused the price of oil to drop and stocks to accumulate. It is almost safe to estimate that within a year or two consumption will again approach production.

Distribution of coal and oil in United States.

In studying the distribution by counties of producing coal and oil fields in the United States, it will be noted that both of these natural resources are widely distributed and in some areas, especially in the eastern states, are found closely associated, but in the areas of the Rocky Mountains, coal production is confined to a small area in the state of Washington and the oil production to California.

In the eastern states competition between coal and oil for railroad purposes can not exist because only a limited amount of crude can be produced and it is of such quality that only a small per cent is available in the form of fuel oil. On the other hand, a good grade of coal is obtainable in large quantities.

On the Pacific Coast, especially in California, these conditions are reversed because fuel oil is available in large quantities and at moderate prices.

In the southern states coal and oil have been in closer competition as a railroad fuel, due to increased production and favorable prices and to large imports of fuel oil from Mexico. Oil is gaining a stronger foothold in this area as evidenced by the fact that many miles of railroad are being converted from coal to oil-burning systems.

Naturally oil has not been considered as a possible fuel for the railroads in the northern United States, but with the recent discoveries of heavy crude oil in such fields as Lost Soldier, Lander, Poison Spider, Maverick Springs, Bolton Creek, Derby Dome, Mule Creek and Hamilton Dome in Wyoming and the Kevin-Sunburst and Soap Creek fields in Montana, the railroads serving this area may find it extremely desirable to use fuel oil, provided they can be assured of adequate supply at reasonable price.

Demand for fuel oil.

The demand for fuel oil for marine and rail transportation and for other purposes is constantly increasing. The quantity of bunker fuel oil supplied at United States ports to vessels engaged in foreign trade increased from 14 000 000 barrels in 1919 to 31 700 000 barrels in 1922, an increase of approximately 226 %. The recognized advantages of fuel oil for marine purposes are so marked that ship operators can afford to pay higher price for fuel oil than can railroads that pass through or near good coal fields. Practically all modern ships are constructed to burn fuel oil and coal burners are rapidly being converted into oil burners.

As a source of power for marine use the oil engine has proved most satisfactory. In a recent test an 8 000 ton vessel equipped with oil engines and having a bunker capacity of 15 300 barrels bunkered at a California port and made the round trip to Europe via Panama Canal, stopping at Boston and New-York on the return voyage, without requiring any additional fuel. In the future the oil engine will no doubt supplant steam equipment to a large extent, should fuel oil become scarce.

The advantages of the oil engine of the Diesel type are not confined to marine purposes, for it is rapidly gaining favor as a motive power in many industries. It is being used with great

success as a prime mover for generating electricity, operating pumps and compressors, and infact, performing most of the duties for which the stationary steam engine has been used in the past. Just recently 34 large units have been ordered by an oil pipe line company to operate 17 pumping stations on a pipe line delivering oil from central Wyoming to western Missouri. These engines vary in capacity from 400 to 600 HP. Oil engines are being used by some railroads to operate day coaches on short runs and it is possible that future development may result in a practical oil engine locomotive. Due to its efficiency and increasing popularity, the oil engine will probably create an ever increasing demand for fuel oil.

Large amounts of fuel oil are used annually for industrial purposes, especially by those industries west of the Rocky Mountains. During the past few years fuel conditions in the Middle West have been such that fuel oil could compete in a limited way with coal for railroad transporation as well as industrial purposes. The oil industry has taken advantage of this situation by encouraging the use of fuel oil and as a result has created a demand to the supply. With the falling off of imports from Mexico it is possible that the demand for this product by the eastern areas will result in a greater demand being placed on the Mid-Continent production.

Economic factors.

When any industry is dependent upon any commodity for its existence it is sound business policy to be assured of a sufficient supply of this commodity at all times to meet its needs. This principle holds especially true of fuel oil required for railroad operation. Unlike coal the production of oil can not be controlled and is subject to a wide variation. Large pools may be discovered and their flush production result in an over supply of oil, a condition which now exists in California and to a less extent in the Mid-Continent field. On the other hand, a large production may be suddenly reduced by water encroachment, as, for example, in some of the large fields in Mexico during the past year.

During the period of over production, fuel oil stocks accumulate and consequently the oil industry makes every effort to create new markets for this product; likewise during periods of coal shortages, fuel oil markets are extended. Markets created under such conditions are the first to feel the effects of a decrease in production and increase in price.

A period of flush production and low price is invariably followed by one of decline in production and corresponding increase in price unless new fields are discovered with sufficient production to make up for the decline of the old fields. The intensive development of a few new fields in southern California has resulted in doubling the oil production of that state in less than a year, and at the same time the market value of the oil has decreased over 40 %. The present low price, however, will not continue, for the production from these fields most certainly must decline, and this decline must be accompanied by a corresponding increase in price, unless new fields with large production are discovered.

Many railroads control or own the mines from which their coal supply, or at least a portion of it is obtained and are thus assured of a supply at all times. For railroads using fuel oil this policy is highly desirable, even more so than in the case of coal.

Before attempting to use oil a railroad should endeavor to control by ownership, contract or other legal means a future supply of fuel oil sufficient to justify the cost of changing over to oil and back to coal. Our known oil

reserves are smaller than our coal reserves and are being more rapidly exhausted. As the supply of oil decreases, many railroads now using fuel oil will find it necessary to resort to coal.

Summary.

Fuel oil possesses many advantages over coal for railroad operation, but there are many economic factors to be considered before deciding upon its use. The supply of oil is not unlimited and, at the present rate of production, we are rapidly exhausting our reserves without using the oil to best advantage. We are experiencing a period of over production, which tends to stimulate new markets and uses, but does not encourage conservation. There exists a world wide competition for oil and by overdeveloping our reserves, we are making it possible for foreign countries to obtain our oil at prices much less than elsewhere in the world.

The present period of overproduction is only temporary, but while it lasts new demands are being created which will be the first to feel the pressure of reduced production accompanied by increased price. An industry dependent upon fuel oil should be assured of a source of supply at a reasonable cost. For a railroad, where the demand is large, it is highly desirable to control sufficient oil production to meet its needs. Some railroads, either directly or indirectly, have found it most profitable to own and operate oil properties, and thus at all times be assured of a fuel supply.

With decreased production, the amount of fuel oil available for railroads and other industrial purposes will depend largely upon the demand for Marine and Naval purposes and for refined products. Since oil has such a market advantage over coal for marine purposes, ship operators can afford to puchase it at prices which would prohibit its use by railroads. The supply of fuel oil will be reduced with the extended use of the cracking process of refining, which must be generally adopted if our future demands for gasoline are to be met. Thus the amount of fuel oil which in the future will be available for railroad use will be affected on one hand by a stronger demand, and on the other by a decreased production resulting from improved refining methods.

Approximately 45 % of the estimated oil reserves in the United States are the heavier oils containing a large percentage of fuel oil and are confined to California, the Gulf Coast states, and the Rock Mountain area. With the exception of the latter, these are the areas in which fuel oil is now being used by the railroad. Considering both the estimated reserves and present rate of production, fuel oil can not be produced in sufficient quantities to enter into strong competition with coal as a railway fuel. In California competition with coal does not exist but in the southern states it does, and as a result some systems burn oil, some coal and others both, while the reserves in the Rocky Mountain area have not been developed to a point where oil has entered into competition.

We are at present reveling in a period of overproduction and a period in which our oil reserves are being rapidly exhausted without apparently giving much thought to the future. The present rate of development is hastening the time when the peak of our production will be reached; just when this will occur, no one can say. Therefore, any railroad deciding to use fuel oil for locomotive operation should be assured of an adequate future supply at a cost which will justify the change over to oil fuel and back to coal.

Colloidal fuel.

The status of the development of colloidal fuel, and the advantages to be anticipated from the extension of its use, so far largely experimental, were fully set forth by Mr. Lindon W. Bates in a paper contributed to the Proceedings of International Railway Fuel Association, 1922, from which the following extracts are quoted :

The purpose of this paper is to present an outline of the nature of colloidal fuel and of its relation to the railroad systems of the United States. Colloidal fuel is a liquid fuel mixture of pulverized coal or coke stably suspended in mineral oil or blended oil and liquid derivates of coal. The fuel may take the form of a true colloid or of a close approximation thereto, but more often it takes the form of a so-called coarse suspension, displaying however certain colloidal characteristics. A typical fuel of the latter type consists of 30 % coal, pulverized so that about 85 % would pass a 200 mesh screen, stabilized in 70 % mineral oil. The fuel is atomized and burned as fuel oil, using the ordinary preheat of the latter.

To prevent sedimentation, a stabilizing treatment is given. This consists in the use of one or more alternative or concurrent measures. 1° Among other features that of intensive grinding. This is to attain a colloidal subdivision of the solids. It is not the preferred system owing to the cost of such grinding. 2° Saponification, which is to obtain an action apparently somewhat analogous to that of protective colloids. This may be secured by adding to the oil a soap, such as a limerosin soap, thereby « fixating » it. About 1 % of rosin (20 lb. per ton of fuel) and 1/2 % of lime will serve. An alkali alone may be employed, which saponifies with the resinous ingredients of the fuel. Resinate of calcium, however, gives the more persistent stability. For example, a stability of several months is readily attained. 3° Peptization. This is obtained by digesting bituminous coal with a moderate percentage of creosote or other coal distillate under a heat treatment of about 180° Fahr. for over an hour. These processes are set forth in detail in a dozen United States patents recently issued, particularly Nos. 1390228 to 1390233 of 28 September 1921.

The principal technical advantages of colloidal fuel are the following : (1) By combining coal or coke, and tar in limited amounts if desidered, with mineral oil, the available quantity of the latter will serve to yield a considerably large amount of liquid fuel. (2) The fine sizes of coal may be given profitable use and a liquid fuel value. (3) The heat units in colloidal fuel are as efficient as those in oil and sometimes more so. The reason why in some cases there is greater efficiency may be attributed (*a*) to the explosion of the solid particles when the absorbed liquid vaporized in the combustion chamber, thereby increasing the area for oxidation beyond the surface of atomized droplets, and (*b*) to less flue gas loss, inasmuch as the hydrogen content of collodial fuel (in view of the coal in the mixed fuel) is less than that of traight oil. (4) Since in most localities heat units in coal or coke are much lower in cost than heat units in oil, the cost of heat units in the mixture will be lower than in oil until the cost of oil falls so low that the cost of manufacture balances the economy. This will usually be the case when oil costs about two cents a gallon. For such reasons colloidal fuel can compete in most localities with oil. It can compete with coal whenever oil can do so, and sometimes where oil cannot. The cost of manufacture is about one dollar a ton. When crude oil is used and the product is topped, colloidal fuel has a further advantage. (5) Since the spe-

cific gravity of colloidal fuel carrying several per cent of coal is greater than that of water, a conflagration can be extinguished with ordinary fire appliances and water. It is also possible to fireproof the fuel in storage by a layer of water on the top surface. This is a feature which has been patented. It means that colloidal fuel can enter cities, where for fire reasons oil cannot without risk or special precautions. There is therefore a wider market for colloidal fuel than for oil. (6) Owing also to the high specific gravity, the mixed fuel in which a good grade of coal or coke is used possesses greater heat value per unit volume than oil, although showing less per unit weight. Like oil, it possesses, of course, much greater heat value per unit of volume and weight than coal. Fewer barrels or cars of colloidal fuel are required than of oil to give the same number of heat units. Where storage space is of importance, as it is on ships and locomotives and in houses, this greater « heat density » of colloidal fuel is of distinct advantage.

Turning now to the relation of colloidal fuel to the various railroad systems, it was the writer's privilege in 1921 to make a transcontinental trip for the special study of this matter. In modern railway operating practice it stands as a recognized fact that liquid fuel, particularly in locomotive service, is in every way superior to solid fuel. On mountain divisions, with their sharp curves and heavy grades, and on divisions where the traffic intensity makes for heavy freight units, the ordinary hand-fired coal burning locomotive has become inadequate. To supplant it there must be substituted either stoker-firing, electrification or the oil burning. Of these alternatives the latter is by far the more economical from the standpoint of capital outlay. This superiority is, indeed,so marked that it has been found profitable to convert and maintain operation on a liquid fuel basis even when the cost of fuel oil per million British thermal units far exceeds that of coal. Recent advances in the price of oil, have however, carried it to a point where the expense is so great that further extensions to a liquid fuel basis can not be considered and reconversion of oil burning divisions to coal has in some cases already taken place and in others is imminent. Reconversion to coal would never take place except under the spur of supposed necessity. This necessity can be averted through increasing the supply of liquid fuel by adding coal to oil.

The Middle Western and Western Railroads are fortunately situated in regard to manufacturing of colloidal fuel. The Mid-Continent crude oils and the Wyoming and Montana lignite coal can be united. The latter is too friable and volatile for satisfactory use as locomotive fuel, but when colloidalized would serve very well, since even further pulverization is requisite and the volatiles, if not topped off, are imprisoned in the liquid medium. The northern Pacific Coast is more favorably situated than the southern, because of the Coos Bay, Stony Canon and British Columbia Coal deposits. The eastern roads are favorably situated in regard to coal for colloidal fuel, but less so for oil. The earth crushed anthracite in Pennsylvania gives a large supply of available solids, but oil would have to be brought from Carribean or Gulf Ports. If the fuel were manufactured on a large scale the economies over coal and oil would be attractive, particularly if crude oils and volatile coals were topped during manufacture of the composite fuel.

Some roads in the Middle West have their own oil supply for a part at least of their requirements. Through colloidal fuel that supply would reach further than now and perhaps avoid the necessity of purchasing oil in the open market. A large element of the cost of

fuel oil is transportation. By locating colloidalizing plants adjacent to coal resources along the line the freight on oil may be minimized. Even the coal sections of the line would benefit through colloidal fuel because the coal could be sized and only the « good » coal delivered to the locomotives, leaving the small coal to make liquid fuel.

The labor problem of the railroads would be assisted to a material extent by the adoption of colloidal fuel. There are today certain roads which have been upon a liquid basis for a generation. They are facing the alternative of finding a cheaper liquid fuel or of converting to coal. On these roads the majority of firemen have never fired a locomotive except by the manipulation of an oil throttle. To change to coal would mean replacing these men in a body or teaching them coal-firing from the beginning. In either case the confusion and expense would be great.

What appropriate conclusion can be drawn from the foregoing? Simply this : A new liquid fuel is available which will economize the oil supply. The fuel has been sufficiently tried on marine and land service to demonstrate its nature and behavior. It has not yet been tried upon a locomotive. The details of the relation of colloidal fuel to the various railroads systems require study and various grades of fuel should be made with the different coals and oils available to the railroads. To do so a unit plant should be located at a suitable place, preferably in the Middle West or Pacific Coast. Some railroad or association of railroad interest should have the courage to lead in so promising a field of endeavor.

Apparatus for the combustion of fuels.

The standing committee of the International Railway Fuel Association have classified rocking grates for the combustion of bituminous coal as follows :

TYPE ONE. — *Cross rocking interlocking finger grates.*

Class *a*. — Full area shaking grates without grates.

Class *b*. — Shaking grates with drop grates, either at front or back.

Class *c*. — Combined frame interlocking finger dumping grates.

TYPE TWO. — *Cross rocking non-interlocking grates.*

Class *a*. — Full area rocking grates without drop grates :

(1) Finger grates (non-interlocking) ;
(2) Herring bone grates;
(3) Box type grates.

Class *b*. — Rocking grates with drop grates :

(1) Drop grates at back of firebox;
(2) Drop grates at front of firebox;
(3) Drop grates at both back and front, to which should be added;
(4) Drop grates approximately midway between back and front.

In 1915-1916 this Committee reported :

It has appeared to your committee that the item of greatest importance from a combustion standpoint is that of the percentage of air opening. Theoretically the best grate from the standpoint of resistance to the passage of air to the fire would be one of minimum material with the greatest possible percentage of air opening equally distributed over the entire surface. Whether in practice this principle gives the most efficient grate is a thing the Committee has not been able to determine.

We find that the percentage of air

opening of 62 cases of bituminous grates varies between a minimum of 25.8 % in one design of interlocking finger grates, and a maximum of 49.6 % in a design of the herringbone type; the average of all cases giving a percentage of 37.2.

The degree of coarseness of grates we have assumed should be expressed in terms of maximum dimension of any air opening. This figure we have found to vary between the limits of 1/2 inch and 1-1/2 inches. Two cases show 1/2 inch as being the maximum dimension of air opening, 19 cases shows 1-3/16 inches and 1 shows 1-1/2 inches. Thus the 1 inch dimension of air opening is found to be the most generally used. The character of the coal and the degree of fineness of same would appear to govern the degree of coarseness of the grates to be used.

The nature of the coal and the degree of tendency to form a clinkery ash will naturally govern the design in that particular reference to the width of the grate bars or length of fingers. It is hoped that a discussion will be provoked as to the feature of the interlocking versus the non-interlocking principle.

Grates.

The grate is the mechanical supporter of combustion, just as oxygen is the chemical supporter, but nothing like a proportionate amount of study has been given to it. Material and design have generally been on a more or less haphazard basis, the iron used being whatever happened to come out of the cupola, and the design following general practice, which may or may not have had originally some good and consistent basis. Inquiries directed to the railroads of the country show that in few cases only have investigations been made as to the proper air opening and that in practically no instances is any attention paid to the grade of cast iron used. We believe, however, that there is no limit, from a combustion standpoint, to the air opening which could be permitted to advantage, and that the theoretically perfect grate would be one in which the fuel supporting bars were of infinitely small section, and the air opening, therefore, 100 % of the grate area. Practically, of course, no such construction is possible, but if this theory be conceded to be true, it naturally follows that we should endeavor to obtain as large an amount of air opening, evenly distributed through the grate bars, as can be done without mechanical loss of fuel. One road is, to our knowledge, experimenting with a grate of the non-interlocking, cross-rocking, finger type, in which an air opening of slightly better than 50 % is obtained. The observations have not been as yet of sufficient duration to afford positive proof as to results, but all indications point to combustion conditions considerably improved over those obtaining with the present standard grate of the road, which gives 36 % air opening. Besides improving combustion by reducing the restrictions imposed on the flow of air to the fire and distributing it more evenly throughout the fuel bed, we may expect a reduction in clinkering. Clinker, in the last analysis, is merely fused ash, and it has been shown that if the temperature of the ash is kept down few clinkers can form. A generous air supply will tend to hold down the temperature, and this action is also apparent in the grate mentioned above.

The matter of interlocking versus non-interlocking fingers is, we believe, one which is open to discussion. The interlocking type introduces features which may tend to cause unnecessary burning of grates as the fingers are long, and it is a frequent occurrence for clinkers to catch between fingers of adjacent sections when same are rocked, either forc-

ing them out of place or rocking them. This type gives, of course, a more pronounced « chopping » action on the fire than the non-interlocking, but we believe that with most coals if a consistent thickness of fire is carried and excessive hooking (tending to cause clinker) is not indulged in, the non-interlocking type offers advantages which are worthy of consideration.

Grate fingers in transverse cross-section should be approximately sections of a frustrum of a cone, with the base up. This shape gives better air inlet conditions than if fingers are rectangular in section, and also allows the grates to clear themselves to much better advantage, as the space between the fingers, through which ash and refuse must pass, is of constantly increasing area below the grate surface.

The material used in making grate bars should be cast iron of maximum strength commensurate with toughness, small shrinkage and high melting point. As a rule it is difficult to control with any degree of exactness the mixture from which grates are cast, as special heats are seldom run for this purpose, the ordinary practice being to use the general casting mixture.

Air openings in grates.

The committee has previously recommended that for the majority of coals in use, the air openings through the grates be as great as is compatible with the mechanical strength of the grate bars. The data secured by the committee for its reports of 1915 and 1916 show that on locomotives burning bituminous coal the air opening in the grates in service runs as high as 70 %, although this is rare. Fifty per cent air opening is not uncommon, and the average of the designs reported to the committee was about 40 %. On locomotives burning anthracite coal the prevailing air opening averaged nearly the same amount, although the maximum was only 45 %.

It is obvious, however, that with certain fine and friable coals maximum grate opening will entail undue waste of coal through the grates; and it is unfortunate that many such coals, like lignite for example, are the very ones which, from the point of view of good combustion alone, ought to have maximum air supply and the greatest air opening in the grates. Such coals clearly call for a compromise in designing the grates. An interesting solution of this difficulty has been made by the Union Pacific Railroad in some of its locomotives burning a light fragile coal resembling lignite. In order to prevent excessive waste of coal through the grates, the grate openings have been kept moderate in size. The air drawn through the grates is consequently insufficient for good combustion, and in order to supply the necessary additional air they provide a small air door which opens into the fire-box above the fire. When the locomotive is in operation this door is constantly open.

It is clear that the air opening through the grates must continue to be determined with some reference to the kind of coal in use, and that for many kinds of fuel grate design must be a compromise between the desire to obtain maximum air opening and the necessity of avoiding undue waste of coal. Under the circumstances, probably no positive recommendations can be made with respect to air openings which would be generally applicable and satisfactory for all fuels.

Table grates vs. finger grates.

While the committee's investigations seem to show a tendency to substitute table grates for finger grates, there is little evidence to prove that under all circumstances there is any clear superiority of one type over the other. Each

type can be so designed as to provide adequate air opening and strength; but there remains much difference of opinion as to the relative merits of the two, and it seems probable that the choice between them must be made with regard to the kind of coal in use. While it seems unlikely that the committee will ever be able to make recommendations of one type or the other which would be universally acceptable, it is nevertheless convinced that the Association needs more information concerning the relative merits of table grates and finger grates, and it hopes that this topic will receive thorough discussion at the Convention.

Composition of grate-bar iron.

The proper chemical composition of grate-bar iron seems to have received but little attention and apparently the majority of roads have no standard specifications and accept any foundry mixture, notwithstanding the general belief that many grate-bar failures are traceable to unsuitable material.

Liquid fuels.

In a paper published in the Proceedings of International Railway Fuel Association 1915 Mr. G. M. Bean briefly but comprehensively covered the requirements in the nature of firebox equipment for the satisfactory use of liquid fuel in locomotive service, in part as follows :

In the combustion of fuel oil, where the steam spray is used for vaporization, we are confronted with the fact that in the process of atomization we start the particles of oil on their way to the flue even before they are partly burned. The first result of these particles coming into the heated portion of the furnace is to separate the carbon from the hydrogen, the carbon thus being left as a fine dust floating unconsumed, to be deposited as an insulating layer of soot, or to be carried out of the stack in the form of black smoke. If these fine particles of carbon were attached, as in a bed of coals, a supply of air could easily complete their combustion. With liquid fuel, therefore, the diffusion must be simultaneous with ignition with the resultant long flame. The surface tension of oil, especially when the particles are finely divided, is such as to make them assume a spherical form of extreme rigidity and, therefore, exposes the least possible area to the oxygen. We are thus brought to realize that large furnace volume is very essential to the burning of fuel oil. While the relative dimensions are of minor import to the volume, it is evident that we must provide a flame passage of sufficient length to prevent unconsumed particles passing to the flues. It was the realization of the limited volume of the locomotive furnace that brought about the change from back to front end burner arrangement a very few years ago, in an attempt to lengthen the flame path. While it is generally conceded that lack of oxygen is responsible for smoke, the writer believes that restricted furnace volume and the attending lack of time for the proper mixture of the gases in the more highly heated portion of the furnace is the most common cause for black smoke from an oil-burning locomotive. One of the difficulties met with in the use of oil in the locomotive is the frequent necessity for the removal of soot from the flues, by means of sanding out. This of course is attended with several disadvantages, not the least of which is the resultant loss of fuel.

Special attention is brought to this point in connection with locomotive oil-burner furnace design because of the general tendency to restrict the furnace volume by carrying draft pan and brick work too high in the fire box, covering up valuable heating surface and bringing about the continual necessity for

forcing the fire at the expense of the remaining exposed surfaces.

As shown above, one of the principal requirements in the burning of oil is to expose the fuel to the furnace heat so that the greatest possible area is presented to the oxygen. A study of the atomization of oil is therefore of some importance, and it will be readily seen that the stretching of the surface of fuel oil is a study of capillary action and that it is not hard to determine the work necessary. Oil in bulk has little surface, but when broken up into fine particles it has the combined surface of the spherical areas of the drops thus formed, and the work of atomization is the work of stretching the surface of exposure.

Theoretically, it should be possible to atomize oil to a definite fineness of spray by means of a mechanical device much more economically than by means of the steam jet. Many attempts have been made along this line with almost as many failures. The writer does not know of a stationary or locomotive furnace which is fired by means of mechanical atomization. Some success has been met with in marine service where the use of air and steam have their disadvantages. The simplicity and flexibility of the steam jet burner now in use on the majority of locomotives is practically the same as the one first introduced in this country, would lead to the belief that, when improvement is made in the oil-burning locomotive furnace, it will not be made in the burner, and from this the writer believes there is much more importance connected with other features of the furnace design than with the burner itself. However, a brief description of burners now in general use might be of interest.

There are two distinct types of oil burners, namely the external atomizer and the internal atomizer. The former has by far the most general use, both in stationary and locomotive practice. The burner of this type used on locomotives consists of a rectangular casting containing two longitudinal passages separated from each other by a horizontal partition. The oil flows through the upper passage to an opening in the face of the burner so arranged that it allows the oil to drool down onto the flat steam jet which issues from a similar but much smaller opening. The steam sprays the oil into fine particles and forces it back to the point of combustion or to the vicinity of the flash wall. Burners of this general type are as follows :

Sheedy;
Von Boeden-Ingalls;
Booth.

The Hammel is the only burner of the internal atomizer type which is used to any extent in the locomotive furnace. This device brings the steam and oil into contact in the burner in such a manner as to leave it in a finely mixed spray of oil and steam. While each of these devices has its supporters and seems to give entire satisfaction in its own field, it only justifies the statement that though atomization is of importance it must be supplemented with correct features in connection with other arrangements and equipment. To bear out this statement of the apparent unimportance of the type of burner, attention is called to the fact that the Booth burner, one of the simplest of all, and now Standard on the Santa Fe Railway, has been in continuous use on that line since oil was first introduced as fuel, and has never failed, in itself, to show up well in connection with any furnace design. In other words, where failures in design or arrangement were met with, it was always traced to other features being wrong, rather than the burner. The type of burner, therefore, seems of minor importance so long as it is simple, substantial, not easily stopped up and easily cleaned. All of the burners above outlined use steam at full boiler pres-

sure as the atomization agent. Experiments with the use of air and superheated steam have been conducted, but no results obtained which were considered of sufficient importance to warrant their use. However, the writer believes that further experiments in the use of superheated steam are advisable, in view of the fact that it is extensively used in stationary and marine service.

Locomotive furnaces are not considered ideal for the use of fuel oil, and for this reason as much as any other there have been as many different furnace arrangements as there have been localities in which oil fuel has been used. At the time of its introduction on American Railways thought was given to the possibility of having to return to the use of coal. The justification of this is seen in many cases, where the return to the use of coal has occurred, on account of the oil becoming scarce or too high in price. Of course, in such localities as California, where an abundance of oil has been found and the price of coal is prohibitive, arrangements for the handling and use of oil have become more permanent, but even here we find no changes in locomotive boiler design to make it more suitable for an oil burning furnace. The frequent necessity for transfer of power from one district to another, as well as the desire to maintain standards, probably accounts for this fact, in view of which it seems somewhat remarkable that such high furnace efficiency has been attained.

At the first inception of the idea in this country, it was natural that the designs used in Russia were followed. The burner was placed under the rear of the fire box, and directed forward with an upward incline so that the flame shot under a low, short brick arch, with the result that combustion became so intense in this limited space as to cause the flame to pass from under the arch with such velocity as to impinge on the door sheet, side sheets and crown sheet, with very detrimental results. Bad water conditions throughout the Southwest aggravated this to such an extent that the life of fireboxes was only about eighteen months or two years and the replacing of them soon became a very severe burden. The back end burner arrangement also required an excessive quantity of fire brick, which not only gave trouble by continually burning out, but also served to cover up valuable heating surface, restrict the furnace volume and throw an increased load on the remaining heating surface. While the back end burner arrangement is still in use to some extent throughout Texas, it has entirely disappeared from every other section. The burner is now placed in the front end of the draft pan and directed toward the rear in such a manner that the draft is forced to reverse the direction of the flame before it passes to the flues. The furnace is open, the brick work kept low and the maximum of heating surface exposed. The correct drafting of this arrangement is still a somewhat debatable subject, but the general idea seems to favor the admission of the principal volume of air through openings in the vicinity of the flash wall, which is built up under the door, it being the plan to admit this air through numerous small openings, preferably circular in shape, and distributed well over the rear third of the draft pan in such a manner that the air is brought in contact with the flame from several directions and not in too concentrated a volume. A small amount of air is also admitted around or under the burner so as to prevent it from overheating, and keep the flame from dragging on the floor of the pan. This arrangement results in a very uniform distribution of heat and the consequent lengthened life of the fire boxes and flues, until now it can safely be said that for service under like conditions, a fire box on a locomotive burning oil will last longer than one in a

coal burner if consideration is given to the extra work possible to be obtained from the oil burner. Oil requires from twenty to thirty per cent more air per pound of fuel than the average bituminous coal. There is a tendency to restrict the air openings in draft pans of oil burners, and the writer has found it very generally the rule that with locomotives of the small class in both oil and coal burner service the oil burner will have the smaller nozzle, indicating the necessity for maintaining a higher front end vacuum in order to draw in the necessary amount of air to make the engine steam properly. This is attended with the added difficulty that the high velocity of the entering air produces a more concentrated column or stream which is difficult to break up, requiring a heavy atomizer, the use of which has its disadvantages.

There is a question that arises here as to whether the open furnace created by the front end burner arrangement is all that can be desired, for it is true that the gases will follow the path of least resistance and the velocity at the center of the combustion space will be much higher than at the sides, this indicating the necessity of some sort of baffle to increase the velocity of flow at the top and sides where the gases wipe the heat absorbing fire box sheets. It is also apparent that when the flame path is surrounded by heat absorbing surfaces, to hasten the process of diffusion and shorten the flame length, the subjecting of the gases to the presence of incandescent baffles is desirable.

Aside from the two furnace arrangements outlined above there is in service on one of the Southwestern railways, as well as on some Mexican railways, what is known as the Hammel furnace. This differs from the others in that it has a burner in both the front and rear of the draft pan directed toward one another, the line of flame of the front burner being slightly higher than that of the rear. This furnace also has the advantage of the low brick work and large exposed heating surface. In fact, the opposing burners do away with the necessity for a high flash wall under the door.

In the two latter types it is the practice to keep the brick low on the sides, and expose all possible heating surface. Fire brick for this service must be of good quality, as the fire box temperatures range from 2 500 to 2 750° Fahr., which with the fluxing action of the salt and alkalies carried in the oil are very severe on it and cause it to give out readily, making frequent renewals necessary. The proper maintenance of brick work is essential to good results, and the possibility of the brick work falling down in the path of the flame must be avoided, as it usually results in an engine failure.

The oil supply is carried in tanks built to fill the coal space of the tender, and piped from there through suitable connections to the burner. It is generally necessary to provide means for heating the oil so as to insure a proper flow, as gravity is depended upon for the necessary pressure. This heating is also an aid in atomizing and various means are provided for the purpose. The original practice was to turn steam directly into the oil, but, aside from an emergency feature, this has been very generally abandoned, as the accumulation of condensation gave trouble in disposal, as well as by getting into the oil line and interfering with the burner operation. The draining of the condensation from the tank was always accompanied by some loss of oil and the direct heating often resulted in overheating the entire contents of the tank with the attending loss. An improvement on this was to place steam coils in the space and heat indirectly. This had some advantages, but it also caused trouble by overheating, and by the pipes leaking at the joints. It is probable that the box

heater is the most desirable arrangement. It is indirect in action, only heats a sufficient volume to insure a supply at the burner, and is not liable to cause trouble by allowing water to get into the oil storage.

The oil storage tanks are provided with suitable gauges or measuring devices to give a check on their contents at all times. Means are also provided for cutting off the supply of oil to the burner in case of accident, such as a wreck or break between the engine and tender. The supply of oil to the burner is regulated by means of a suitable valve placed near the burner and operated through connections by the fireman. In some climates it is necessary to provide an auxiliary heater in the pipe line to reheat the oil before it goes to the burner. Such a heater should be used only when necessary, as an extensive heating tends to carbonize the oil in the supply line and the burner.

Smoke consumption.

Smoke consumption or rather the reduction of the emission of visible products of combustion (smoke) is considered to be dependent upon the following factors which are set down in the order of their relative importance :

(1) Design and maintenance of the locomotive particularly the boiler and appurtenances such as ash pan, grates, combustion space and draft appliances to allow development of the boiler capacity at the rate of combustion giving greatest fuel efficiency.

(2) Character of fuel particularly as to volatile content and percentage of « slack » or very small sizes.

(3) Operation of the locomotive with particular reference to correct firing practices, uniform rate of combustion and steam consumption insofar as practicable and co-ordination of the work of the engineer and fireman.

(4) Appliances for promoting combustion and increasing boiler efficiency, such as the brick arch and approved blower.

(5) Appliances for suppressing the emission of visible products of combustion, such as steam jets discharging into the combustion space, entraining air and mixing it with the products of combustion in the firebox.

(1) The principles involved in so balancing the design of the locomotive that ample air supply is provided to support the combustion, are well understood. In order to insure a design which will produce satisfactory results in the direction of smoke suppression, the application of these principles to the original construction is of fundamental importance and full weight must be accorded the consideration of the particular fuel which is to be used. Given the locomotive construction in accordance with these principles, it follows as the condition next essentially important that the maintenance of parts subject to wear and mal adjustment be given strict attention and that the machine be thus kept in first class operative condition.

(2) Where the conditions of operation are such as to permit and to make such a course desirable, the use of selected coal low in volatile content will be found to aid materially in the suppression of objectionable smoke emission, and the sizing or grading of the fuel to reduce the percentage of slack or dust will be found advantageous. The judicious use of a sprinkling hose by wetting the coal just sufficiently to prevent instantaneous release of the volatile content of the firing charge will promote a more gra-

dual release of the smoky constituents of the fuel and give a better average combustion with less objectionable smoke emission.

(3) The methods employed in the operation of the locomotive by the engineer and fireman stand next in importance in their relation to « smokeless » operation. Controlling conditions permitting the best results will be obtained from a fuel bed of practically uniform depth or thickness giving uniform rate of combustion throughout the area with the supply of fuel regulated to as nearly a uniform rate as practicable corresponding closely to the work of the locomotive and the resultant demand for steam. Careful co-ordination of the work of the engineer and fireman is necessary. The rate of steam consumption, water supply to the boiler and fuel supply to the firebox must be correctly timed as only experience in each specific case can direct, before suppression of smoke can be made a practicable accomplishment.

Granted that the locomotive design is such that as required for the work to which it is assigned and that it has been maintained in good operative condition, no special appliances can be expected in the matter of smoke control, to take the place of careful methods of handling upon the part of the members of the engine crew.

(4) It is generally accepted in this country that a brick arch of proven stability in the locomotive firebox promotes combustion of the prevailing fuel coals of relatively high volatile content by reason of the aid to the maintenance of high combustion space temperature and the mixing effect of the baffle action upon the gases as well the lengthening of the path of gas flow.

The use of an approved quick action blower is considered desirable as an aid to smoke control. The ability to obtain instantaneous blower action at full capacity in case of un-expected closing of the throttle is of great assistance to the fireman in this connection.

(5) Appliances such as steam jets discharging a mixture of steam and air into the combustion space of the firebox below the arch, mixing the hot gases and providing an excess of oxygen insuring complete combustion and possibly to some extent diluting the products of combustion, have been used to a limited extent on locomotives assigned to service requiring their operation in yards lying in zones covered by restrictions upon the emission of smoke and also upon locomotives in road service operated through such zones.

Elaborate tests of such appliances were made in 1912 and 1913 on the locomotive testing plant of the Pennsylvania Railroad Company at Altoona, Pa., and a complete report was made in 1913 to the American Railway Master Mechanics Association and published in full in the Convention Proceedings, with recommendations covering the application. No later data have appeared to alter the conclusions then reached and subsequent applications of the principles have followed substantially the lines then indicated.

Some administrations have objected to such appliances as being costly in maintenance and as tending to encourage careless practice upon the part of the engine crews.

Mechanical stokers.

The mechanical stoker for locomotives is a development of the past twenty years, in response to the necessity of securing greater capacity from single power units.

The mechanical stoking of the modern heavy locomotive permits the handling of more tonnage at higher sustained speed and greater average dependability than would be practicable with hand stoking and the development of the mechanical stoker has made the use of locomotives designed to burn coal continuously at a rate much in excess of the capacity of any fireman to supply it by hand.

It is generally considered that a tractive capacity of 50 000 lb. or a coal consumption of 4 000 lb. per hour will justify the use of a mechanical stoker. The present commercial production of mechanical locomotive stokers in the United States is confined to the overfeed or « Scatter » type, manufactured by four companies. On 1 November 1923, there were 7 856 mechanical stokers in service or on order, according to information furnished by these companies.

Good practice in the firing of locomotives with mechanical stokers has been outlined by the International Railway Fuel Association committee on firing practice as indicated by the following extracts :

The successful and economical performance of a stoker depends, first, upon the proper condition of its parts, and, second, on proper operation (granting, of course, that the locomotive may be in proper condition).

The things that constitute proper firebox conditions on hand-fired locomotives similarly apply to stoker-fired locomotives.

It should be understood that a mechanical stoker is in no sense automatic.

For economy in firing locomotives which are equipped with mechanical stokers, your Committee recommends the following practices :

Before a fire is built in a locomotive, the distributing features of the stoker should be inspected and known to be in proper condition.

The fire should be free from clinkers and banks when the locomotive is delivered to the engine crew.

Before leaving outgoing track, engine crew shall see that :

(*a*) Fire is clean and in good condition;

(*b*) Stoker parts are properly oiled;

(*c*) Stoker is working properly.

The stoker should not be used in building up the fire, either by roundhouse force or engine crew. Build up the fire by using the hand shovel. Commencé the operation of the stoker as soon after starting the train as conditions require.

The fire should be maintained with the hand shovel when standing, drifting or doing short switching.

Use shovel to hand fire spots in firebed which may be « thin » or undersupplied by stoker. In that way maintain a uniform distribution of coal over entire grate surface. Every square foot of burning surface requires coal.

On the stoker-fired locomotives the throttle, reverse lever and injector should be operated with the same regard for economy as with hand-fired locomotives.

Because of the « thinness » of the fire on stoker fired locomotives greater care should be exercised when shaking the grates than is required on hand fired locomotives. If practical, grates should be shaken only when the locomotive is not using steam.

Attention should be given coal as it feeds into conveyor, removing any foreign material which would tend to clog or interfere with the operation of the stoker.

Fuel should not be fed faster than it is being consumed. Adjust the speed of the stoker to requirements.

Carry a bright level fire, reasonably thin.

Frequently observe the condition of the fire to know that it is properly maintained. Best results are obtained by continuous stoker operation, care being taken not to crowd the fire.

Avoid popping, stopping the stoker if necessary.

See that the locomotive, the fire and the firing apparatus are properly adjusted to produce the minimum amount of smoke.

When approaching grades the fire should be properly prepared, to meet the heavier demands. Do not wait until the train is on the grade before speeding up the stoker.

Before beginning a descending grade or before taking on coal the conveyor slides should be closed.

Overloading of tenders should be avoided.

In case the stokers stops, due to clogging by foreign matter, the stoker throttle should be closed before any attempt is made to remove the obstruction. The fire should be maintained by hand until such time as opportunity may present to remove the obstruction.

When approaching terminal, have all slide plates closed. This should be done at a sufficient distance so that without waste all coal may be worked out of conveyors.

The engine crew should close all valves of stoker apparatus before leaving the locomotive.

On arrival at terminal the engineer should report on regular work report, for correction, improper distribution or other stoker defects which may exist.

A thorough inspection and test should be made of the stoker before locomotive is put in the roundhouse. Defects should be reported in customary manner.

Spark arresters.

A front end or smoke box netting is the common form of spark arrester employed on locomotives in this country. It is usually so located as to extend from the table plate at an angle of about 40° to the forward part of the smoke box. Various sizes of netting opening are used governed by local conditions, as to kind and characteristics of the fuel used. Removable sections provide for access to the parts of the smoke box located behind the netting. A modification of the arrangement is the use of perforated plates in whole or in part to make up the spark arrester. The design presents some difficulty in the maintenance of tight joints where the netting joins the cylindrical surface of the front end extension, and in the matter of easy access to the rear of the netting.

In the endeavour to obviate these disadvantages many designs have been developed along the general plan of an enclosure surrounding the exhaust jet joining with the table plate at the base and with the stack extension at the top, taking various shapes, cylindrical, basket forms, box forms, etc.

These designs permit ready access to the rear of the exhaust stand for inspection of steam pipes, superheater parts, etc. Easier removal or repair of the spark arrester itself, when so constructed is another advantage.

APPENDIX.

Out of the twenty-three railroads which responded to a questionnaire upon the subject of fuel and its combustion :

Eighteen roads reported that 100 % of locomotive fuel is coal. — Average annual consumption of these roads amounts to 48 000 000 tons and the average cost delivered to locomotive tenders varies between $2.50 and $5.20 per ton.

Five roads located in the anthracite region mix the low cost small sizes of anthracite — « rice and buckwheat sizes » — with bituminous to effect a reduction in average price of the fuel. No other roads reporting practice mixing coals.

None of the reporting roads use peat or lignite.

Five reporting roads use from 40 % to 100 % oil fuel at an average cost varying from $1.09 to $1.30 per barrel of 42 gallons. 25 000 000 barrels per year is consumed by these roads. The gravity ranges from 14° to 25° (Baume) and the heat content from 17 250 to 19 000 British thermal units per pound.

None of the roads reporting use pulverized or colloidal fuel.

Four of the roads report using special mixture (semi-steel) for casting grates. Twenty-one use rocking grates. Two (South American) roads use stationary grates. Two roads in the anthracite region use grates rocking on longitudinal axes. All others use grates rocking on axis at right angles to center line of boiler (cross rocking).

Five roads use 100 % interlocking finger grates and five use 100 % « table » grates. Most of the balance of the reporting roads use a high percentage of « table » grates. Average percentage of opening compared to total grate area varies between 15 % and 50 % with the major portion around 40 %. Standard air space width varies from 1/2 inch to 1 inch with 3/4 inch as the most common standard.

The oil burning roads report the use of seven makes of burner — Booth — Van Boden — Ingles — Sheedy — Best, Best No. 3 and one local standard. All burners are located at the front end of the fire box. Air opening varies from 26 % to 40 % of net flue area and is arranged around the burner and at bottom and sides of the pan.

Eight roads reporting use no mechanical stokers. Fifteen roads reporting use 3 677 mechanical stokers of six manufactures on locomotives ranging in tractive capacity from 48 700 lb. to 160 000 lb. Advantages stated consist principally of the development of greater locomotive capacity. The characteristics sought are good fuel distribution, reliability in operation, and facility of maintenance.

For aiding in smoke suppression, four roads reporting, use steam jets at the firebox, two use the multiple jet blower and quick opening blower valve at the smoke-box, six depend upon the effect of the brick arch and the balance use no special application to suppress smoke.

[621 .135.2 & 625 .214]

REPORT No. 1

(America)

ON THE QUESTION OF REDUCTION OF THE COST OF TRACTION : LUBRICATION OF AXLEBOXES FOR ALL ROLLING STOCK (SUBJECT IV-B FOR DISCUSSION AT THE TENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION), (1)

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Figs. 1 to 6, pp. 1057 to 1084.

This report on the question of lubrication of axleboxes for all rolling stock will be confined to the consideration of the question as its applies to conditions and practices effective on the American railroads and particularly the railroads of Canada and the United States of America.

I — ANSWERS TO QUESTIONNAIRE SUBMITTED.

Questionnaires were prepared and sent to forty-five different roads, and answers were received from twenty-three of the above roads.

A. — Axleboxes, plain bearings, roller and ball bearings, locomotives and cars.

COMPOSITION AND MANUFACTURE.

1. **Supply detailed drawings of axleboxes as applied to the journals of the following :**

a) **Locomotive leading truck wheels.**

b) **Locomotive driving wheels.**

c) **Locomotive trailing wheels.**

d) **Locomotive tender wheels, freight and passenger car wheels.**

a) Typical drawing, figure 1, shows leading truck axlebox;

b) Typical drawing, figure 2, shows locomotive driving wheel axlebox;

c) Typical drawing, figure 3, shows locomotive trailing wheel axlebox for outside journal truck;

d) Typical drawing, figure 4, shows axlebox for freight car with arch bar truck, and the same for passenger car with pedestal type truck.

(1) This question runs as follows : « Lubrication of axleboxes for all rolling stock : *a*) Axleboxes; plain bearings; roller and ball bearings. — *b*) Lubricants. »

2. Supply detailed drawing of shield or fitting adopted to prevent water or dust from penetrating into boxes.

Detailed drawing, figure 5, shows dimensions of various dust guards for different sizes of American Railway Association standard journal boxes. Also typical drawing of journal box lid for the same type boxes, figure 4.

The general practice on American roads is to use plain wood dust guards; 68.36 % using plain wood, or plain wood with tin strips inserted at ends. One of the above roads uses old plush on back of guard while three others use No. 4 White Canvas Duck tacked on the back of guard with 4 oz. tacks for all dust guards, while one road only uses these on tender axleboxes; and, one uses Virginia Compensated Dust Guard of wood with springs for adjusting same for use on passenger cars. One road uses plain wood guards or those made of three layers of laminated wood fastened with wire stitches. Two roads use guards made of three layers wood as above. One of these also uses the same guard with pressed steel edges on same and adjustable springs. One road (South American) uses plain wood dust guard with steel plate closure over opening, plate being bolted on. Another South American road uses two styles of guards, one being an outside metal dust guard clamped with bolts on dust guard seat. The other of wood with steel plate on outside forming a casing, and is adjustable for size. Closure of slot being effected with steel plate bolted on.

3. State angle included at center of journal by arc of contact.

Locomotive leading trucks.

Average angle included at centre of journal by arc of contact is 129° 55′ while the minimum angle reported was 109° and the maximum angle 180°. 52.6 % of the replies received indicate that angles used are 120° or under.

Locomotive driving wheels.

Average angle included at centre of journal by arc of contact is 172° 16′ while the minimum angle reported was 140° and the maximum angle 180°. 73.7 % of the replies received indicate that angles used are approximately 180°.

Locomotive trailing wheels.

Average angle included at centre of journal by arc of contact is 129° 6′ while the minimum angle reported was 108° and the maximum angle 180°. 53.3 % of the replies received indicate that angles used are 120° or under.

Locomotive tenders, freight and passenger car trucks.

Average angle included at centre of journal by arc of contact is 108° 3′ while the minimum angle reported was 70° and the maximum angle 180°. 93.8 % of the replies received indicate that angles used are 120° or less.

4. What is the pressure per square inch on journal, calculated on the projected area, *i. e.*, on the chord of contact (C) multiplied by the length of bearing neglecting the fillets or radii?

Locomotive leading trucks.

Average pressure in lb. per square inch on the projected area is 183.1 lb. while the minimum pressure was 118 lb. and the maximum pressure was 234 lb. 52.3 % of the replies received were under the average pressure of 183.1 lb., while 23.8 % of the replies received were over 200 lb. pressure per square inch.

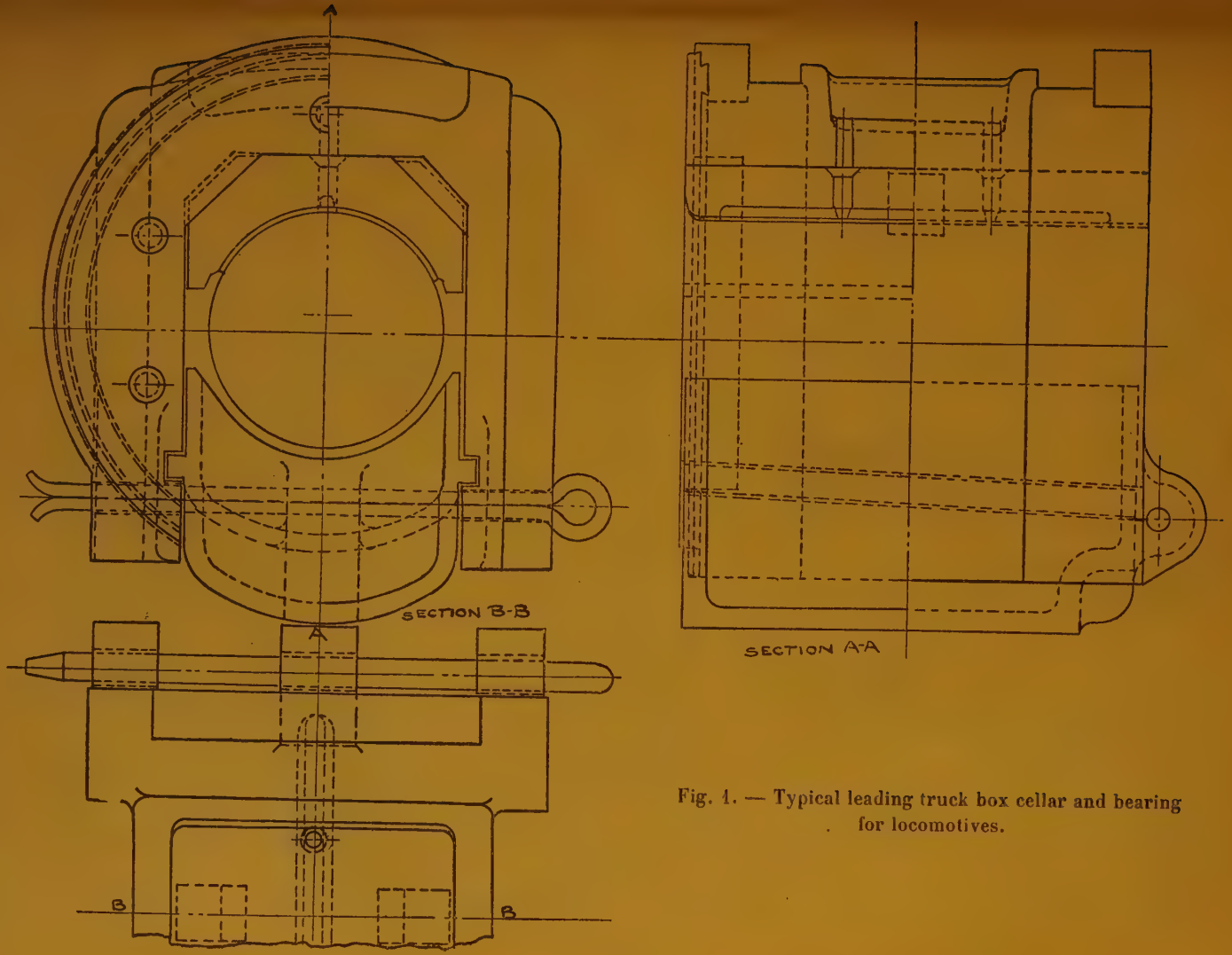


Fig. 1. — Typical leading truck box cellar and bearing for locomotives.

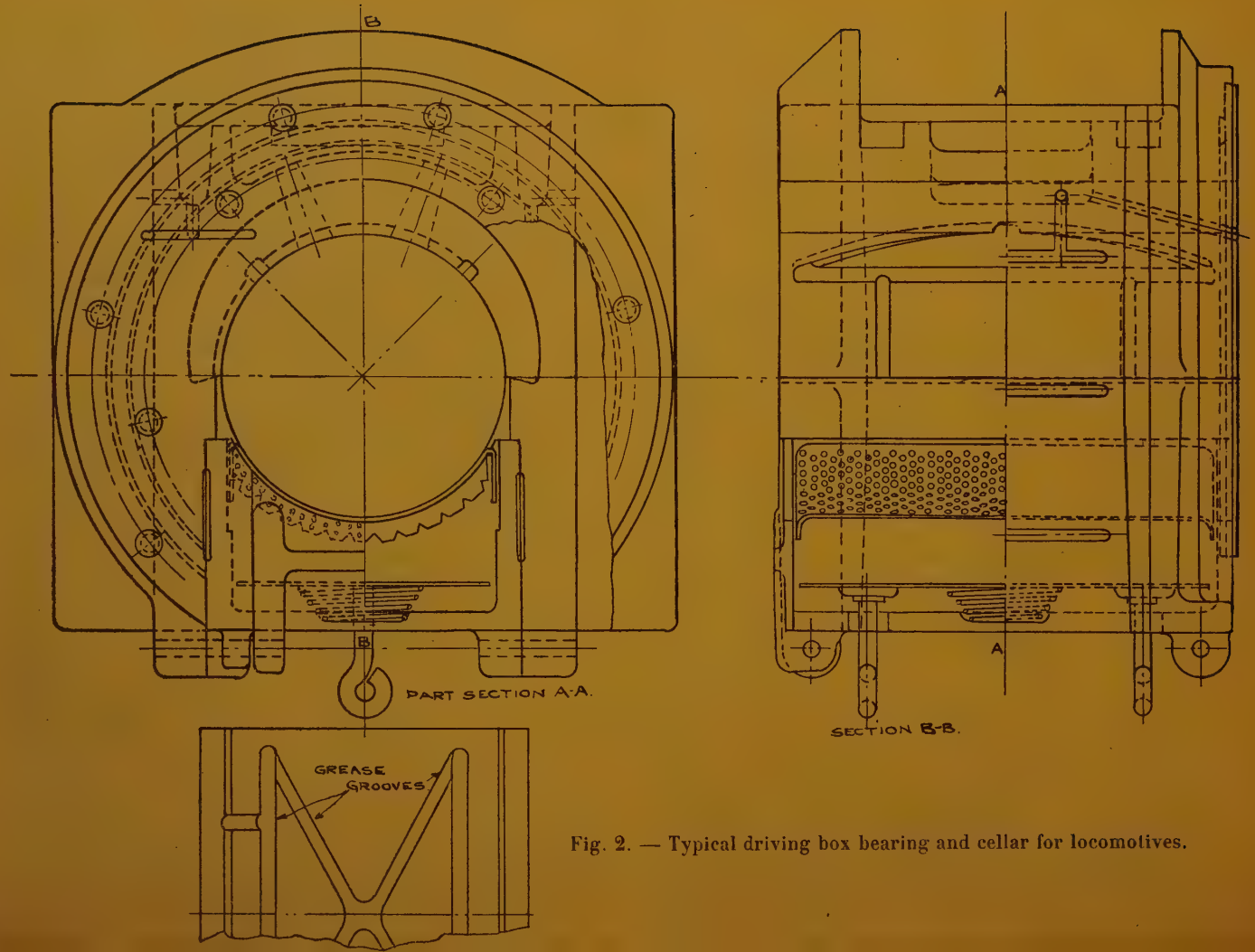


Fig. 2. — Typical driving box bearing and cellar for locomotives.

Locomotive driving wheels.

Average pressure in lb. per square inch on the projected area is 173.5 lb. while the minimum pressure was 104 lb. and the maximum pressure was 258 lb. 50 % of the replies received indicate that pressures used are above the average while 43 % use pressure above 200 lb., some in all wheels and others not.

Locomotive trailing wheels.

Average pressure in lb. per square inch on the projected area is 218.1 lb. while the minimum pressure was 150 lb. and the maximum pressure was 298 lb. 66 % of the replies received indicate that pressures used are over 200 lb. per square inch. Present practice apparently to use about 250 lb. per square inch.

Locomotive tenders, passenger and freight cars.

Average pressure in lb. per square inch on the projected area of all these wheels is 380.42 lb. while the minimum pressure was 114.5 lb. and the maximum pressure was 563 lb. per square inch.

For passenger cars, average pressure in lb. per square inch was 364.25 lb. while minimum pressure was 260 lb. and the maximum pressure was 563 lb. General practice is apparently to use from about 300 to 400 lb. pressure per square inch.

For freight cars, average pressure in lb. per square inch was 435.75 lb. while minimum pressure was 164 lb. and the maximum pressure was 563 lb. General practice apparently to use from about 450 to 500 lb. pressure per square inch.

For locomotive tenders, average pressure in lb. per square inch was 373.7 lb., while minimum pressure was 114.5 lb. and maximum pressure was 561 lb. per square inch. General practice is to use about 400 lb. per square inch.

5. Give maximum and minimum size of radii or fillets of journals.

Locomotive leading trucks.

Four roads use 1/4 inch radius, eleven use 3/8 inch radius; one uses both 1/4 and 3/8 inch radii, and one uses 13/16 inch radius. (South America.)

Locomotive driving wheels.

Two use 1/4 inch radius; one uses 1/4, 5/16, and 3/8 inch radii; five use 3/8 inch radius; one uses 3/8, 1/2 and 5/8 inch radii; four use 1/2 inch radius; one uses 5/8 inch radius and two use 11/16 inch radius.

Locomotive trailing wheels.

Inside journals :

One uses 1/4 inch radius; two use 3/8 inch radius and one uses 1/2 radius.

Outside journals :

One uses 1/4 and 3/4 inch radii, two use 1/2 inch radius, thirteen use 3/4 inch radius, two use 13/16 inch radius, and one uses 7/8 inch radius.

Locomotive tenders and car journals.

3 3/4 × 7 inches axle.	1/4 inch radius journal to dust guard fit.							1/8 inch journal to collar.			
4 1/4 × 8 —	5/8	—	—	—	—			1/8	—	—	—
5 × 9 —	3/4	—	—	—	—			1/8	—	—	—
5 1/2 × 10 —	3/4	—	—	—	—			1/8	—	—	—
6 × 11 —	3/4	—	—	—	—			1/8	—	—	—

Note. — All tenders use same radii of fillets as cars with one exception which read (South America) uses 9/16 inch radius on 5 × 9 inches journal.

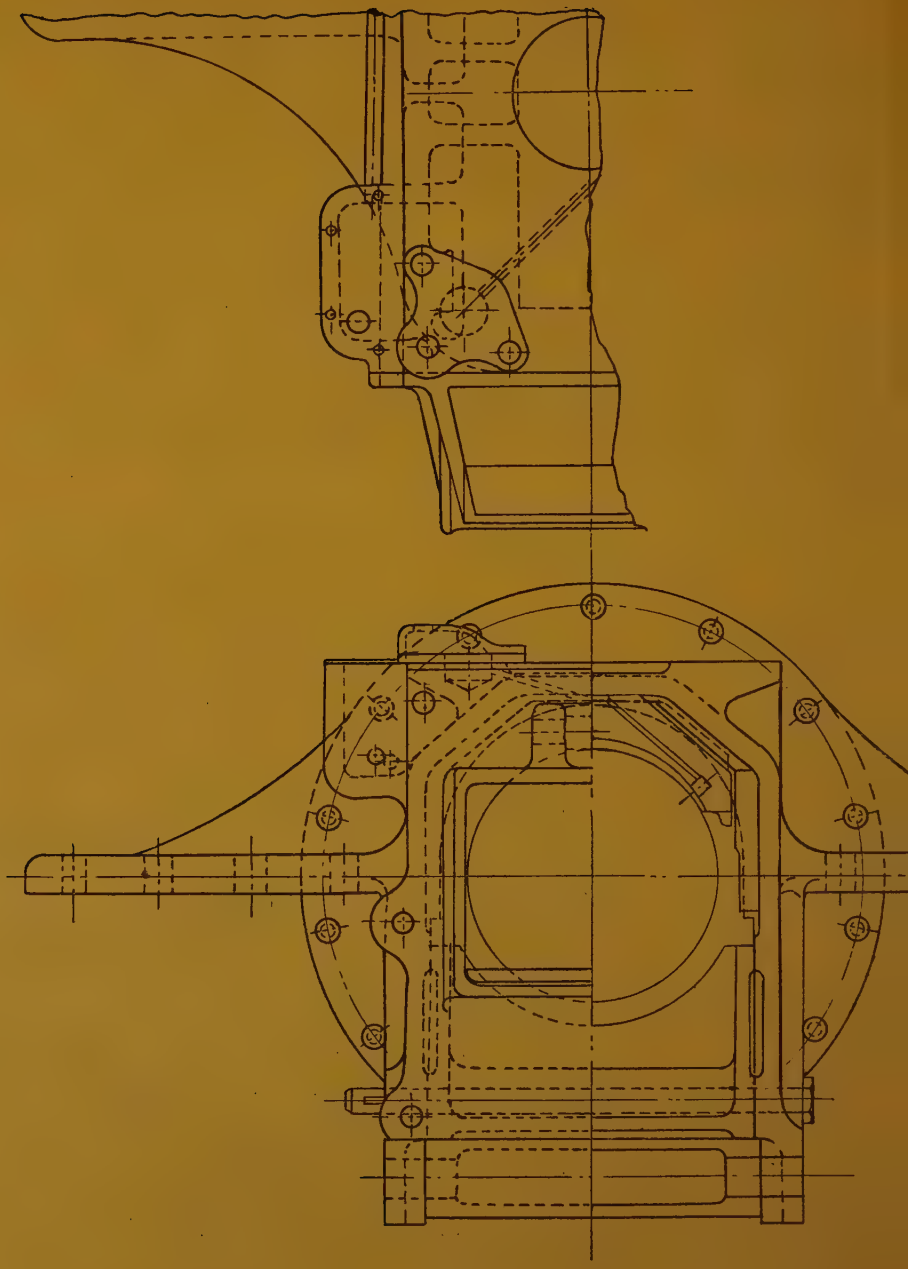
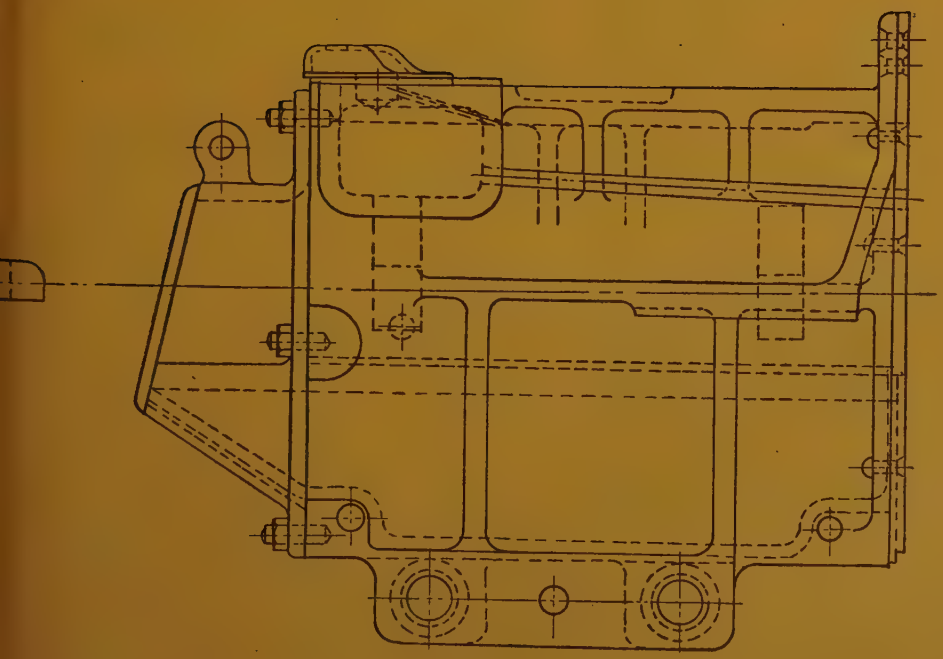


Fig. 3. — Typical trailing truck box and cellar for locomotives.



6. **What method is used for bedding the journal bearing or crown brass to the axle in first application of same?**

Locomotive, engine, trailing and tender truck bearings.

General practice on American railroads is to bore to size and fit with file or scraper or both. Two roads bore to size and apply. One does no fitting whatever.

Locomotives, crown brasses.

General practice in this country is not to fit driving boxes to journal, but to bore out on machine and apply to journal. Nine roads bore boxes and spot them to fit by filling and scraping. Twelve bore to neat size of box for all boxes. Four bore 1/100 inch large for all boxes. Two bore all boxes 1/64 inch large. One bores 0.003 inch large for every inch of journal diameter. One bores main 1/100 inch large and others 1/32 inch large. One bores main boxes neat size and others 1/64 inch large.

Freight and passenger cars.

General practice in this country is to do no fitting other than boring to size, or also easing off crown and sides by filling for freight cars. One road uses cutting mandrel of same diameter as journal. For passenger cars general practice on 50 % of roads reporting is to fit by filing or scraping.

7. **What method is used for burnishing or polishing the journals before application of the bearing?**

General practice in this country is to roll with hardened steel roller, held in tool post securely against journal with oil under same. One road files journal before rolling. One road grinds off smooth as possible, filing and cleaning off with emery cloth before rolling. Three roads either roll as above or polish with emery cloth and oil.

8. **Is journal or axle removed after a certain limit of wear is reached, or after having made a certain mileage? State wear or mileage limit.**

Locomotives, driving axles.

General practice is to remove after reaching Interstate Commerce Commission's condemning limits which are as follows : engine driving, trailing and engine truck axles more than 1/2 inch below original diameter except when all axles are the same diameter when, other than main driving axles can be worn to 3/4 inch below original diameter. Tender axles when worn to 1/2 inch below original diameter. Two roads remove engine truck axles when reduced 1/4 inch below original diameter. Three remove when 3/8 inch below original diameter. One road removes main driving axles when worn 1/2 inch below original diameter and others when 3/4 inch below original diameter. One road also removes after reaching the above limits or after being seven years in service. One road removes from service driving axles in Pass. engines when worn 3/8 inch below original diameter, in service six years or has made 400 000 miles. Freight engines when worn 1/2 inch below original diameter or in service seven years or has made 450 000 miles. Switch engines when worn 1/2 inch below original diameter or in service six years. Freight engine truck axles when worn 3/8 inch below original diameter or in service nine years. One road removes from service after they have reached a certain mileage. One removes balanced compound

driving axles after they have made 275 000 miles regardless of wear. One removes after limit of wear is reached, which limit varies according to importance of stock. One road removes from service after limit of wear is reached, which is graduated according to load on journal.

Car axles.

General practice is to remove after American Railway Association and Interstate Commerce Commission condemning limits are reached; these mean when worn 1/2 inch below original diameter or when journal is increased 1/2 inch in length over original or collar worn to 1/4 inch in thickness or less. In addition to the above, one removes after seven years in service. Two remove when reduced 1/4 inch below original diameter; and one removes when in shop if reduced 7/16 inch below original diameter. One removes after limit of wear is reached, which is graduated according to load on journal.

9. What is the composition of the axlebox brass?

Locomotive crown bearings.

Number of roads using.	*Lead.*	*Tin.*	*Copper.*	*Zinc.*	*Phosphorus.*	*Nickel.*	*Iron.*	*Other metals and impurities*	*For what used.*
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent	Per cent.	Per cent.	Maximum per cent.	
1	17.9	7.3	75	8	...	...	...	...	Crown bearing.
1	10 to 14	8 to 10	75 to 80	...	...	...	...	3	Locomotive bearing.
1	14 to 20	7 to 10	75 to 80	...	...	...	...	0.2	— —
1	15	8	77	...	...	...	...	...	— —
1	15	8	76.75	...	0.25	...	...	...	— —
1	10	9	80	1	...	...	...	...	— —
1	25	4.5	68	2	...	...	...	0.5	— —
1	9 to 11	9 to 11	77 to 81	...	0 7 to 1.0	...	...	...	Phosphorus crown bearing.
	10	19	80	...	...	...	...	1.0	Special crown bearing.
1	10 to 15	8	80	...	0 to 1.0	...	...	...	Engine bearings.
1	8 to 13	8	82	...	0.4 to 1.0	...	...	1.0	— —
1	14 to 20	7	77	...	0 to 0.25	...	...	2.0	— —
	8 to 15	8	80	...	0.25 to 1.0	...	...	1.5	Phosphorus crown bearing.
1	14 to 20	7	77	...	...	...	...	2.0	Main crown bearing.
	20 to 28	5	72	...	...	...	...	3.0	Other locomotive bearings.
1	14 to 20	7	71	...	...	...	...	3.0	Locomotive bearings.
1	13	9	78	...	...	...	...	...	— —
1	Balance	7	75	...	...	...	...	2.0	Crown bearing.
1	...	10	88	2	...	...	...	...	Locomotive bearings.
1	10 to 15	8	76 to 80	Balance	0.1	1.0	0.15	2.0	— —
	Arsenic trace, Aluminum trace, Antimony 0.30, Sulphur 0.05								
1	30	...	64	5	..	...	...	...	Bearing metal.
1	Stone's Bronze. All locomotive bearings.								

Engine truck and trailer truck bearings.

Number of roads using.	*Lead.*	*Tin.*	*Copper.*	*Zinc.*	*Phosphorus.*	*Nickel.*	*Other metals and impurities*	*For what used.*
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Maximum per cent.	
1	10 to 14	8	75	3	...	...	1.0	Engine truck and trailer bearing.
1	10 to 14	8 to 10	75 to 80	...	...	..	3.0	Locomotive bearings.
1	15	8	76.75	...	0.25	...	...	Bearing metal.
1	30	...	64	5	...	1.0	...	— —
1	25	4.5	68	2	...	...	0.5	— —
2	10 to 15	8	80	...	0.1	...	...	— —
1	10 to 15	6 to 10	75 to 80	5	...	...	1.0	— —
4	16 to 24	5 to 7	67 to 77	...	...	...	4.0	All journal bearings.
1	20 to 28	5	72	...	...	...	3.0	Locomotive bearings.
1	14 to 20	5	72	...	...	...	3.0	Journal bearings.
1	13	9	78	..	...	...	...	All bearings.
1	...	10	88	2	...	...	...	— —
1	10 to 15	8	76 to 80	Balance	0.10	1.0	2.0	All locomotive bearings.
1	Aluminum trace, Antimony 0.3 %, Iron 0.25 %, Sulphur 0.05 %, Arsenic trace.							
1	Stone's bronze. All locomotive bearings.							

Car journal bearings.

Number of roads using.	*Lead.*	*Tin.*	*Copper.*	*Zinc.*	*Phosphorus.*	*Nickel.*	*Other metals and impurities.*	*For what used.*
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Maximum per cent.	
6	16 to 24	5 to 7	67 to 77	3	...	...	0 to 4.0	Journal bearings.
1	10 to 16	6	75	3	...	...	1.0	— —
1	7	9	78	6	...	...	...	— —
1	5	8	76.75	...	0.25	...	...	Bearing metal.
1	30	...	64	5	...	1.0	...	— —
1	16 58	6.51	75.65	Trace	Iron 0.6	...	..	Journal bearings.
1	10 to 15	6 to 10	75 to 80	5	...	...	1.0	— —
1	16 to 24	5 to 7	67 to 70	...	...	...	...	— —
1	20 to 28	5	72	..	...	...	3.0	Crown and journal bearings.
1	14 to 20	5	72	...	...	...	3.0	Journal bearings.
1	13	9	78	...	...	...	...	All bearings.
1	...	10	88	2	...	...	...	— —
1	16 to 24	5 to 7	70 to 74	3	...	...	4.0	Journal bearings.
1	Stone's bronze. All locomotive bearings.							

10. If white metal is used, state composition.

Lining metal for journal bearings.

Number of roads using.	Tin.	Antimony.	Zinc.	Antimony plus tin.	Arsenic.	Lead.	Total other impurities.	For what used.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Maximum per cent.	
5	3 to 5	8 to 10	....	1 to 14	0.2	85 to 88	0.5	Lining metal.
1	5	10	...	...	...	85	...	— —
1	1	10	...	...	...	89	...	Tenders, cars.
1	4	14 to 18	...	...	...	75 to 82	...	Engine truck and trailer.
1	5	7	...	...	...	88	...	Lining metal.
2	...	13	...	...	...	87	...	— —
1	...	7.4	1.35	Iron 0.86	...	81	...	— —
1	5	10 to 11	...	...	...	83 to 85	...	— —
1	50	12	...	...	...	38	...	— —
1	9 to 11	9 to 11	...	...	...	80	...	Lining truck and trailer.
	2.5 to 3	7.5 to 8.5	...	...	...	89 to 91	...	Car and tender bearings.
1	5	8 to 10	...	...	...	85	....	Lining metal.
1	...	12 to 14	...	...	...	86 to 88	0.75	— —
1	21	11	...	...	...	68	...	— —
1	40	17	...	Copper 3.0	...	40	...	Locomotives.
	...	6	...	...	...	94	...	Cars.
1	6 to 8	9 to 11	...	...	...	84	...	Car journal bearings.
	0.5 to 1.5	3 to 5	...	...	...	94 to 96	...	New bearings.
1	80 to 85	7 to 9	...	Copper 6 to 8	...	...	...	Locomotive and cars.
1	Tandem « A » White metal, Eyre smelting Co. Tonbridge England.							Cars.
1	Stone's Railway « A » metal.							

11. Are pockets of axlebox brasses tinned before white-metaling? Give particulars of precautions taken to insure the surface being thoroughly tinned, or state what other methods are used, if any.

General practice on American railroads is to bore to size, heat, clean with muriatic acid or otherwise, dip in bath of molten tin, and place on mandrel while hot and pour lining metal on. Two clean with zinc chloride solution in dilute hydrochloric acid. Two use sal-ammoniac. One tins by rubbing with solder (50-50); one by rubbing with stick tin while one dips in bath of molten solder. One coats rough part of brass not to be lined with clay paste before heating.

Of the above, we find that the following

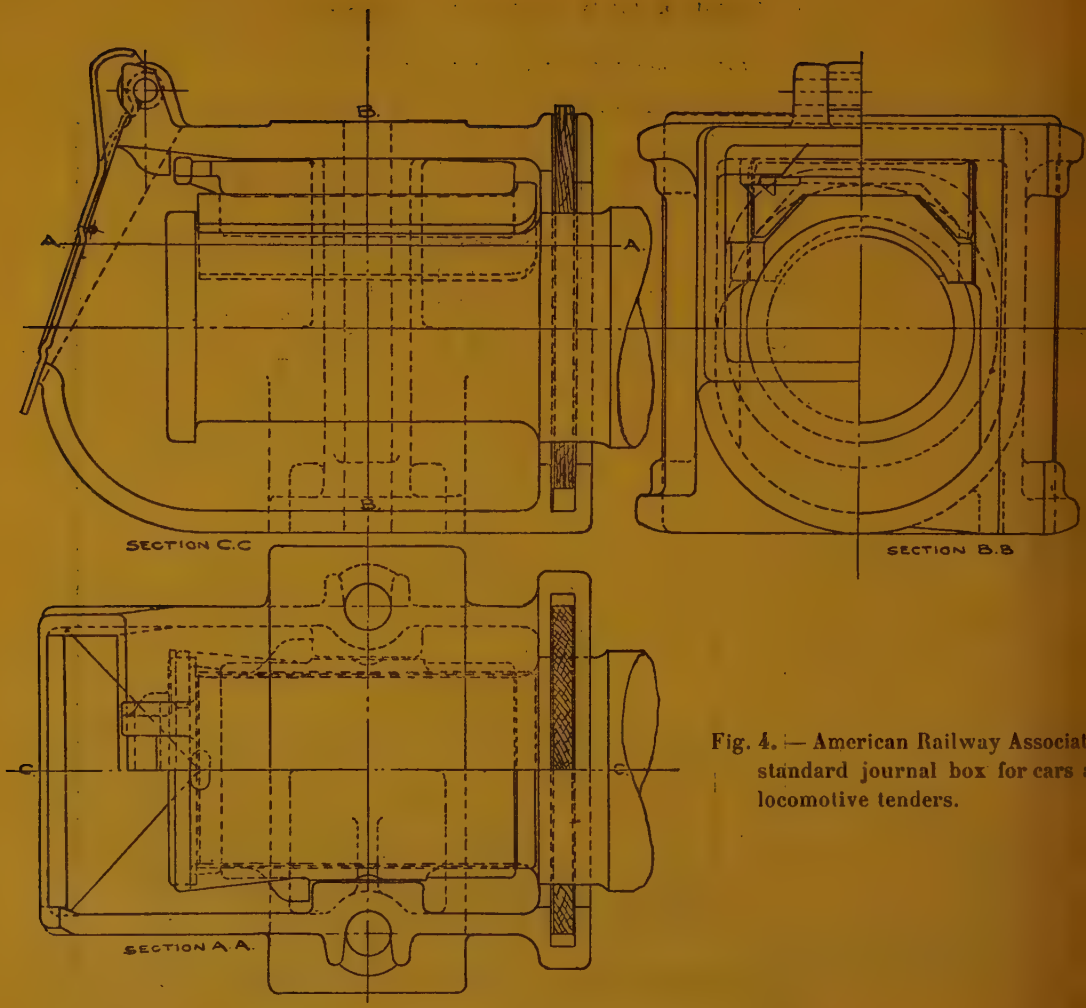


Fig. 4.—American Railway Associat standard journal box for cars locomotive tenders.

bearings are dovetailed to hold lining metal in place :

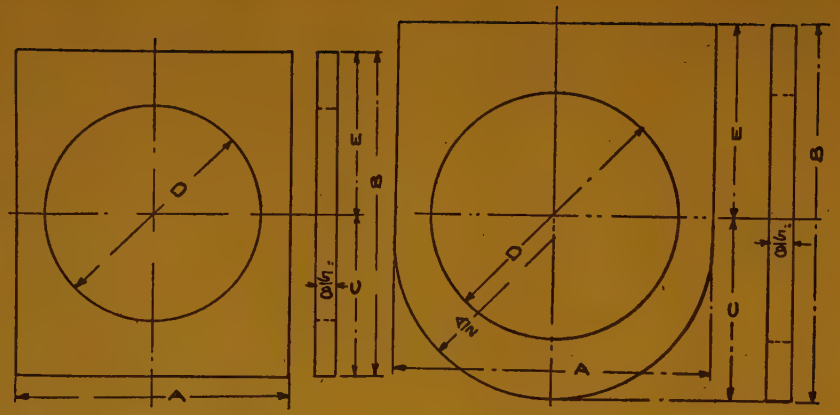
Leading truck bearings.

Thirteen use two strips of babbitt dovetailed in and from 3/4 inch to 1 3/4 inches in width.

One uses seven strips of lining metal dovetailed in and running diagonally across face of bearings, 1 1/16 inches in width and 5/8 inch deep.

Trailer truck bearings.

Seven roads use two strips of lining metal dovetailed in and from 3/4 inch to 2 inches wide.



A. R A. designation of dust guard.	Size of journal.	A	B	C	D	E
A	3 3/4" × 7"	6"	7 1/2"	3 3/4"	4 13/16"	3 3/4"
B	4 1/4" × 8"	7 1/4"	8 3/4"	4 3/8"	5 5/16"	4 3/8"

A. R A. designation of dust guard.	Size of journal.	A	B	C	D	E
C	5" × 9"	8"	9 1/2"	4 5/8"	6 3/16"	4 7/8"
D	5 1/2" × 10"	8 7/8"	10"	4 7/8"	6 11/16"	5 1/8"
E	6" × 11"	10 5/8"	10 3/4"	5 1/8"	7 5/16"	5 5/8"
F	6 1/2" × 12"	11"	11 5/8"	5 3/8"	7 13/16"	6 1/4"

Fig. 5. — American Railway Association standard journal box dust guards.

Tender truck bearings.

One uses two strips of babbitt 1 1/2 inches wide by 1/4 inches thick dovetailed in. One uses lining metal all over surface of bearing except strips 3/8 inch wide at edges, all dovetailed in.

Crown bearings.

In addition to the above, four roads report using babbitt strips on crown bearings. These being located on both sides of centre and from 5/8 inch to 3 inches wide and dovetailed in.

12. Give full particulars of oil, groove in bearing (if not already shown on detailed drawings called for in question 1), *i. e.*, position, shape and depth of groove.

Leading truck bearings.

General practice in the United States is to have from two to three oil holes in tops of bearings and centre oil groove on face of bearing from 1/2 inch to 1 1/4 inches wide and from 3/8 inch to 3/4 inch deep; or to have outside oil channels on top of bearings and two oil holes through top with centre oil groove 1/2 inch to 7/8 inch wide and 1/4 inch to 1/2 inch deep.

Driving wheel crown bearings.

General practice is to use two grease grooves in bearings, one on each side of centre and connected at ends by cross grooves 3/8 inch by 3/8 inch. One uses three grooves, one at centre 3 1/2 inches by 3/4 inch and two at sides 5/8 inch square, all three connected by cross grooves. Five roads use one centre groove as follows : one 3 1/2 inches $\times$ 1/2 inch, one 2 inches by file cut depth; two 1 1/4 inches and 1 inch wide. Rest use two grooves 45° from centre and from 1/2 inch to 3/4 inch wide and from 3/8 inch to 1/2 inch deep. For use with oil, centre groove is used of size about 1/2 inch wide by 1/2 inch deep.

Trailing truck bearings.

General practice is to use outside oil channel on top of bearing in centre with from one to three oil holes leading to centre groove on inside face of bearing from 1/2 inch to 1 inch wide and from 3/8 inch to 1/2 inch deep. Two use four 3/8 inch holes leading to inside face of bearing near edges on side. One uses only centre groove on inside face of bearing with one oil hole in top of bearing.

Tender and car truck journal bearings.

No oil grooves are used in these bearings on any railroads replying.

13. Are journal bearings removed from the journals for examination? If so, state the time or mileage period.

General practice on American railroads is not to remove journal bearings at any stated time or mileage limit for inspection.

For passenger cars : one road examines every thirty days, one every four months, three every six months; of these last one when in shop and once during heavy travel period; one when in shop and where terminal facilities permit every six months. Others inspect whenever surfaces are exposed for repairs.

For freight cars : two examine every twelve months, and one also whenever trucks are torn down. One every six months and whenever necessary. One when on shop tracks for general repairs

and if on shop tracks at other times when they have not been repacked within nine months.

For locomotives : one examines journal bearings in passenger locomotives every thirty days; freight engines every ninety days, and switch locomotives as required. Driving wheels are inspected generally at shopping periods and also whenever wheels are removed for any purpose.

14. What reduction in thickness at the crown of the bearing or axle box is allowed for wear before re-metaling or scrapping?

General practice is to remove when lining metal is worn through or cracked. One removes when worn 3/16 inch; three when worn 1/4 inch, one when worn 3/8 inch and one when worn 1/2 inch; one when worn 3/4 inch, minimum thickness of 3/8 inch allowed. One road removes as follows : 4 1/4 inches × 8 inches, 5 inches × 9 inches and 5 1/2 inches × 10 inches when minimum thickness of 3/4 inch is reached. 6 inches × 11 inches when minimum thickness of 7/8 inch is allowed, before scrapping.

15. State if possible, percentage of hot boxes per annum, classified into locomotive leading truck, locomotive drivers, locomotive trailing truck, locomotive tenders, freight and passenger cars. Also give average miles made per hot box.

In a good many cases the information as received was not in the form requested, and tabulations following give the best information obtainable.

Average percentage of all hot boxes on equipment from three roads as follows :

	Per cent.
Locomotive leading truck	0.247
Locomotive drivers	0.197
Locomotive trailing truck	0.024
Locomotive tenders	0.0945
Freight cars	97.94
Passenger cars	0.8492

Average percentage of all hot boxes occurring on locomotives and tenders only as follows for five roads :

	Per cent.
Locomotive leading truck	31.99
Locomotive drivers	42.38
Locomotive trailing truck	8.50
Locomotive tenders	18.35

Average percentage of hot boxes occurring on all journals in service of the different classes shown, on two roads :

	Per cent.
Locomotive leading truck	3.45
Locomotive drivers	0.865
Locomotive trailing truck	2.52
Locomotive tenders	1.30

Average miles made per hot box on seven roads including all locomotive boxes whether truck or driving and all tender truck boxes :

Average miles per hot box	82 707
Minimum miles per hot box.	27 500
Maximum miles per hot box.	169 111

Average miles per hot box on freight cars on eight roads :

Average miles per hot box	68 569
Minimum miles per hot box.	15 368
Maximum miles per hot box.	300 000

Average miles per hot box on passenger cars for six roads :

Average miles per hot box	556 210
Minimum miles per hot box.	209 838
Maximum miles per hot box.	1 116 234

METHOD OF LUBRICATION.

16. **Is top feed from reservoir in axlebox crown, and underfeed lubrication used? Give particulars. If top feed is provided by means of an auxiliary oilbox, say in what position this is fitted.**

Locomotive leading trucks.

General practice is to cast oil cup or cavity in top of box for oil feed to top of bearing. Other cavities being cast for oil feed to hub and pedestals or hub only. Seven have oil cups cast integral with box with oil feed to top of bearing. Of these, one also has cavity feeding pedestals only; one to both hub face and pedestals and five feed to hub face only. Four have cavities in top of boxes to feed to top of bearing only. Two have cavities feeding to hub face and pedestals only and five have cavities feeding top of bearing and hub face only.

Driving wheels using grease only.

General practice is to cast one or more cavities in top of box for waste and oil feed to hub and shoe and wedge faces. Three have oil and waste feed from one or more cavities to shoe and wedge faces only.

Driving wheels using oil only.

General practice is to cast one or more cavities on top of box for waste and oil feed top of bearing, hub and shoe and wedge faces.

Locomotive trailing trucks.

General practice is to cast oil cup integral with box at outer end of rear corner with oil feed to top of bearing and pedestals or hub faces. Ten use oil cup for feeding top of bearing and hub face. Two use oil cup for feeding oil to top of bearing only. Nine use oil feed from cavities to hub face and pedestals. One uses oil cup fastened to front of box with feed to top of bearing and feed from cavities to pedestals. One uses oil cup cast integral with box and connected with 1/2 inch wrought iron pipe to side of trailer box.

17. **Give details of packing used for underfeed lubrication.**

General practice is to use saturated waste and car oil. Oil used in the proportion of 3 to 4 pints per pound of dry packing waste. One uses resilient wool packing. One uses 70 parts wool and 30 parts cotton threads. One uses 60 parts wool and 40 parts cotton. One uses 100 wool for locomotives and passenger cars, and 50 parts wool and 50 parts cotton for freight cars. Two use plain cotton waste. Two use spring journal box packing, *i, e.*, cotton threads mixed with 13 or 14 brass springs to the pound of packing. One uses plain cotton waste for freight cars, while locomotives and passenger cars use 40 parts cotton threads, 40 parts wool and 20 parts vegetable fibre. Another uses the same for freight cars and 75 parts wool and 25 parts cotton threads for passenger cars and locomotives. One uses wool waste for freight cars, cabooses and switching locomotives and spring journal box packing for passenger cars and locomotives.

Locomotive driving boxes.

Driving journal compound is used on all but one road which reports an exception in the case of locomotives used in switching service for which a special soft grease is used.

18. State periodical or mileage limit for examination or renewal of packing.

Locomotives.

General practice is to inspect every trip and renew when necessary, also at times of changing wheels or bearings and at class repairs. One inspects trailer and tender boxes on freight engines every thirty days, passenger engines every fifteen days in summer, and in winter as may be necessary. One inspects passenger engines weekly and renews as necessary. One inspects every thirty days and renews as necessary, one renews every three months, one renews every four months, one renews every six months and one every twelve months.

Locomotive tenders and freight cars.

General practice is to inspect every trip and renew if necessary. One examines every thirty days and renews if necessary. One renews every three months, one every four months, one every six months. One renews freight cars every six months, tenders and passenger engines every thirty days, freight engines every ninety days and switching engines as required. Five renew every year.

Passenger cars.

General practice is to inspect every trip and renew if necessary. One examines every thirty days and renews if necessary, two renew every four months, and five every six months. Of these last, one renewal is when in shop and one during time of heavy travel. Two renew every twelve months.

19. What is the average life of packing, oil or grease?

Average life of oil packing.

This is generally not known, but the general practice is to examine and if necessary repack all passenger engines leading truck boxes at the end of each trip. The same would apply to trailing and tender truck boxes. One road reports six months, three one year. One reports leading truck, trailing and tender trucks renewed each general shopping, and turned over periodically in between to prevent glazing on top. One reports engine trucks repacked at each terminal and trailing and tender trucks as they go through shop for general repairs.

Average life of grease packing.

This generally not known. One road reports every six months, one reports at every general repair; one reports grease cakes last three weeks in larger freight locomotives. One reports not removed unless necessary account of repairs.

20. Give methods used for reclaiming oil packing or grease removed from boxes.

Oil packing.

General practice in reclaiming is to use the « hot oil » or « centrifugal » process. With the « hot oil » process, foreign matter is picked out over a wire mesh screen, passed through hot oil vat, pressed or drained out to remove excess oil and resaturated with oil, either pressing or draining out to proper oil content. With the « centrifugal » process, oil is first extracted from old packing and filtered. Dirt or foreign substances shaken out of old waste. Waste is then

resaturated with oil, and pressed or drained out to proper oil content. Ten roads using « hot oil » process, seven of these draining oil out to proper content. One places old waste scrap in a centrifugal machine and extracts oil therefrom. Seven roads using centrifugal process. One first places old packing in steam heated vat and drains out as much oil as possible. One places waste in shredder after oil is extracted and gins out all dirt and fine particles, before resaturating. One road puts used packing through a « tern » de-oiling plant for oil recovery and waste cleaning. This plant separates the oil and foreign matter from the waste by a special process, using a centrifugal machine and a special process with vacuum steam and a solvent. The oil passes into a still which distills the solvent from the oil. The solvent being condensed and used over again. The recovered oil passes to a tank from which it is drawn by vacuum into a filter tank where all sediment is removed.

Recovered waste is placed in a steam drying apparatus where hot air circulating fans dry out the moisture. It is then placed in a de-dusting machine and is shaken and dust extracted, dust passing to a deposit outside the shop, while the heavier particles of dirt fall to a trap at the bottom of the machine.

Recovered oil is mixed with new oil and used for saturating packing for freight cars. Waste for resaturating is placed on trays and slipped into saturating tanks which are sealed hermetically and air exhausted until a vacuum of 25 inches is obtained when the oil is admitted and waste allowed to soak for about 20 minutes, when the saturating tanks are opened and waste removed and placed in drainage tanks where the surplus oil is drained off.

One road reports old packing reclaimed by means of a solvent and waste washing (trichlorœthylene) 50 % new oil is added to oil extracted. Packing used in freight cars only.

Grease packing.

General practice is to remove foreign substances and dirt and pick out serviceable grease by hand and either press through perforated plate with 1/2 inch holes, two or three times to thoroughly mix same, and then press into cakes or press direct into cakes. One reclaims by using half and half old and new grease. One removes from heavier to smaller locomotives and re-uses. One uses after cleaning as above for pin grease. One reclaims by boiling process.

21. **Are any special instructions given to keep the journals and lubrication in good condition when the engine is out of use, and particularly in cold weather?**

No special instructions are given in this case.

MECHANICAL LUBRICATION.

22. **If mechanical lubrication is used, give details of application, where used and troubles experienced. (This to include mechanical means such as pumps or splash devices that have been found satisfactory.)**

Two roads experimenting with mechanical lubricators for leading truck and trailer bearings. This mechanical lubricator has a pump that delivers the oil to the bottom surface of the journal. The oil thus delivered is spread by a pad of sponging that is also in contact with the journal. One road advises great sav-

ing in time and labor as result of using same. One road reports considerable oil wasted by spilling out of box making consumption quite high. Experimenting to overcome same. One road reports mechanical lubricators not in general use but has made some tests with mechanical lubricators of various designs. Another road reports experimenting with a device which apparently gives a favourable consumption. Still another road reports about 5 % of locomotives equipped with « Wakefields Mechanical Lubricator », and advise no trouble experienced with same.

23. Give oil or grease consumption in pints or pounds per 100 miles run.

With the first mentioned lubricator, consumption records have been established indicating that in individual instances, 300 miles have been made per pint of oil per bearing. On others 265 miles have been made per pint of oil per bearing.

With the « Wakefield Lubricator » one road reports the average consumption is 0.35 lb. of oil per journal per 100 miles.

24. Has any trouble developed account of journals running hot?

No trouble has been experienced with the journals running hot.

25. State periodical or mileage limit for examination or renewal of grease or oil packing.

With the first mentioned type of mechanical lubricator, no definite time limit has been established for the inspection of the lubricating device, but locomotives are permitted to make a round trip without attention and then the replacement of the oil used is frequently all that is necessary. With the « Wakefield Lubricator » the life of the oil packing is not definitely known.

26. State if roller or ball bearings have been used or experimented with for axlebox journals. If so, say which journals are fitted, and give particulars of such bearings, and supply drawings if possible.

Two roads report having experimented with roller bearings for cars but no data is available regarding same.

B. — Lubricants

27. Is the oil used a mineral oil exclusively, or a mixture containing vegetable or animal oil?

General practice is to use a mineral oil exclusively. Compositions of oils furnished roads under guarantee contract on a mileage basis, not known definitely but they are made from mineral oils. Some roads report using a mineral oil with a lead soap base. Two roads (South America) report using a mineral oil with 2 % of rape seed oil mixed with same.

28. Is the composition of the oil, varied according to the season of the year? If so, give composition if available?

General practice is to vary the oil used according to the season of the year. Two roads vary for locomotives only, not changing for cars. One reports not changing for tenders or cars. One road does not vary for any equipment.

From those available, average compositions are as follows : winter grade, mineral oil compounded with from 3 to 5 % lead soap while summer grade may be straight mineral oil or 80 % well oil with 20 % cylinder oil stock and a minimum of 3 % lead soap.

29. Give particulars as shown below, of the various mixtures :

Efflux time by Redwood viscometer at 20°, 40° and 100° C.

Specific gravity at 15.5° C.

Setting-point (cold test).

Following are tabulations showing efflux time, specific gravity and setting points of oils used.

Number of roads using.	Grade of oil.	Efflux time in seconds by Redwood Viscometer.			Specific gravity 15.5° C.	Setting point (cold test).
		20° C.	40° C.	100° C.		
1	Summer.....	...	130° F.	...	...	32° F.
	Winter.....	...	140 sec. 80 sec.	...	...	0° F.
1	Summer.....	...	512 sec.	65 sec.	0.8805 to 0.8850	— 20° C.
	Winter.....	311 sec.	122 sec.	41 sec	0.8874 to 0.9012	7° C.
1	Winter.....	790 sec.	243 sec.	47 sec.	0.915	— 40° C.
1	Locomotives..	...	100° F.	150° F.	...	...
	Summer.....	...	1 265 sec.	204 sec.	0.913	...
1	Locomotives..	60° F.	100° F.	150° F.		
	Summer.....	5 500 sec.	940 sec.	220 sec.	0.90 to 0.915	...
	Winter.....	3 500 sec.	600 sec.	155 sec.		
	Cars.....	3 000 sec.	600 sec.	155 sec.	0.91 to 0.915	Not above 20° F.

Number of roads using.	Grade of oil.	Efflux time in seconds by Universal Staybolt Viscometer.		Specific gravity 15.5° C.	Setting point (cold test).
1	Summer.....	210° F.	70 to 80 sec.	19-23° B.	+ 20° F.
	Winter.....	210° F.	40 to 50 sec.	19-23° B.	+ 0° F.
1	Summer.....	210° F.	65 to 70 sec.	...	35° F.
	Winter.....	210° F.	50 to 55 sec.	..	0° F.
1	Summer.....	...	...	27° B.	32° F.
	Winter.....	...	...	27° B.	0° F.
1	Winter.....	100° C.	68 sec.	21° B.	..
1	Summer.....	212° F.	60 to 80 sec.	...	30° F.
	Winter.....	212° F.	35 to 55 sec.	...	0° F.

30. *a*) **Where oil lubrication is used state how often journal boxes are completely refilled.**

b) **If grease lubrication, state method of application and grease used? Also periods of examination and inspection.**

a) *Freight cars :*

There are no general practices followed for periods between refillings. About 50 % of roads have no definite time limit for refilling. Two completely refill according to American Railway Association. Rules; one refills every three months, one every six months, four every twelve months and at heavy repair times and one whenever wheels are changed.

Passenger cars :

There are no general rules followed for completely refilling boxes. 50 % of roads report no definite time for completely refilling. One refills every three months, five every six months, and one every six months and when in shop for general repairs. Local passenger cars have boxes completely refilled every 1 000 to 2 000 miles. One road refills whenever wheels are changed.

Locomotives :

There are no general rules followed for completely refilling boxes. One reports trailer and tender boxes on passenger locomotives refilled every fifteen days in summer and in winter as found necessary; freight engines every thirty days and switching locomotives as required. One refills every three months, two refill every six months and one every twelve months. One refills passenger tenders every thirty days, freight tenders every ninety days and switching locomotive tenders as required.

b) Where grease lubrication is used, which is on locomotive driving boxes only, grease is applied in cakes the shape of the journal and the size of the cellar with a perforated plate the exact shape of the journal on top of the grease and a flat metal plate under grease with a coil spring to hold same against the journal, the heat generated by the friction of the journal in turning softens the grease while the spring pushes it through the perforated plate against the journal. Driving journal compound is used for this purpose, it is mainly composed of petroleum cylinder oil stock, soda soap, some free alkali as NaOH and a small percentage of water. Some manufacturers use only the cylinder oil stock and soda soap in compounding this grease. One road reports using a special soft grease for engines in switching service, but composition was not given.

Periods of examination and inspection as follows :

General practice is to inspect after each trip and refill if necessary. Three refill every six months and one every twelve months; one examines passenger locomotives every thirty days, freight locomotives every ninety days and refills if necessary.

31. **Give grease and oil consumption in pounds or pints per journal for 100 miles run, classified into locomotive leading trucks, locomotive drivers, locomotive trailing trucks, locomotive tenders, passenger and freight cars.**

In most cases information as to the consumption of lubricants on the roads of America, are kept in the form of miles run per pint of different lubricants used per car or per locomotive, and is not

available for 100 journal miles. Available information given below.

Locomotives.

One road reports 9.22 miles run per pint of all lubricants including driving journal compound per locomotive.

One reports 49 miles run per pint of car oil, 193 miles per pint of car oil per locomotive tender. 300 miles run per lb. of driving journal compound. All as per locomotive or tender.

One reports 18.2 miles run per pint of car oil and 118.4 miles run per lb. of driving journal compound per locomotive.

One road reports 32 miles run per pint of car oil and 219.8 miles run per lb. of driving journal compound per locomotive.

One reports ordinary locomotives consume 1.34 lb. of driving journal compound and Mallets 2.41 lb. of driving journal compound per 100 miles run per locomotive.

One reports 2.4 pints car oil and 0.256 lb. of driving journal compound used per 100 miles run, per locomotive.

One reports 5.936 pints of car oil and 1.18 lb. of driving journal compound per 100 miles run per locomotive.

One reports 0.1762 pint car oil per 100 journal miles run for engine, trailer and tender trucks per locomotive.

One reports 1.27346 pints of car oil consumed per 100 journal miles per locomotive for all lubricants.

One road reports 0.00124 pint car oil per 100 journal miles run, while for driving journal compound 0.00044 lb. per 100 journal miles was used.

One reports for driving wheels only the consumption of car oil was 0.1515 pint per 100 journal miles.

Two roads report 0.035 and 3.65 lb. of car oil used respectively per 100 journal miles.

Freight cars.

One road reports 213.24 miles, one 415 miles, one 417.6 miles and one 725 miles run per pint of car oil.

One road reports 0.1688 pint per 100 car miles and one 0.00124 pint, one 0.0112 pint and one 0.0156 pint of car oil consumed per 100 journal miles.

One road consumes 0.0566435 pint and one 0.074 pint of car oil per 100 journal miles run, and one road reports 0.055 lb. of car oil per 100 journal miles run.

Passenger cars.

One road reports 175.19 miles, one 180 miles, one 417.6 miles and one 508 miles run per pint of car oil per car.

One road reports 0.356 pint and one 0.27992 pint of car oil used per 100 car miles.

One road reports 0.00124 pint, one 0.0304 pint, one 0.037 pint, and one 0.071824 pint of car oil consumed per 100 journal miles run.

One road reports 0.055 lb. of car oil consumed per 100 journal miles run.

32. Has any method been adopted for refining oil which has been used and extracted from axleboxes, when the latter are lifted? What are the results obtained?

One road refines oil after same is extracted from the old packing in a centrifugal cleaner in order to remove the water placed in same during process of extraction. Results obtained are good. All other roads when reclaiming old packing run the oil through a filter in order to remove the solid matter in suspension in the oil, in some cases about one-half new oil is mixed with the filtered oil before using for resaturating packing. In other cases if there is sufficient

filtered oil on hand to meet the requirements, no new oil is added. With either condition as stated above the results are satisfactory.

33. **Are bonuses allowed for oil economies made in oil consumption?**

General practice is not to pay any bonuses for economies made in oil consumption. One road (South America) reports no bonuses paid, but fines may be applied for excess consumption. One road (South America) reports a fixed bonus paid which varies according to the grading of the engineer and covers economy in lubricating oil, materials and fuel taken together.

II. — GENERAL DISCUSSION.

MANNER OF LUBRICATING JOURNALS.

Considerations governing choice.

The choice of the design of means for lubricating a journal is necessarily influenced by the considerations of cost, ease and accessibility in repairing, reliability and cost of operation, and last but not least the wheel or truck on which to be employed also governs within certain limits the design of same.

In the selection of the type of lubrication to be employed, the limitations for cars, both passenger and freight are very much more closely drawn than for locomotives; as both classes of cars are interchanged in service under load or light, and go to all sections of the country away from the owning roads, necessitating a means of quick repair with standard material for repairs in order to avoid delays, payment of per diem, loss of service of the car and inconvenience to the shipper and loss of money which may occur due to a falling market. While for locomotives, special means for lubricating the journals may be employed due to the fact that they do not ordinarily leave their home territory where material for repairs is at all times on hand, and where men skilled in the construction of such special devices are available to look after their operation and repair.

With a total number of freight cars on line on class 1 railroads of the United States averaging daily 2 467 954 for the three months period ending 31 March 1924; and of passenger cars of all kinds owned totaling 109 038, and locomotives in passenger and freight service totaling 47 796; the importance of providing a reliable and quickly repaired method of lubrication for the journals can be very readily appreciated.

DESIGN OF BEARINGS.

Plain bearings.

With respect to the various designs of bearings used, plain bearings with an under feed of oil are used almost exclusively for passenger and freight cars and locomotive tenders. The American Railway Association has had for some years a standard for journals and bearings of various sizes to be used on different capacity cars, both passenger and freight. These bearings are comparatively easy of manufacture, and can be made at any brass foundry and machined and metal lined at any ordinary re-

pair shop along the railroad, so that standard material is always at hand for repairs to cars brought in on the repair tracks account of heated journals, avoiding the necessity of having material shipped from owing railroad with the consequent delay and loss of service of the car.

Roller and ball bearings.

Roller bearings have been experimented with by several railroads but enough has not yet been learned about same to justify serious consideration of their adoption generally by railroads. The first cost of application of these bearings is very high and until this can be considerably lowered it almost precludes the possibility of their adoption generally.

On motor cars used on branch lines, or, where equipment stays at all times, roller bearings are being used quite extensively. For heavier cars, considerable trouble has been experienced with the rollers breaking in service. Also, with present cost of lubricating per 1 000 miles of about 5 or 6 cents, it would take a long while to get back the cost of application.

MECHANICAL LUBRICATORS.

The field embraced by this subject is quite broad and the explorations into same are still in their infancy. Several devices of this kind have been developed, but none have been found to be entirely successful and reliable enough to warrant their adoption generally.

These lubricators depend in all cases upon a pump to supply the oil to the journal. One lubricator does this by a direct drive through ratchet gearing and a lever operated from the valve motion; in others, the pump is driven by a cam on the driving wheel axle and in one case from a plunger connected to a pump piston. Plunger being operated by lateral thrust of leading truck wheels.

For car journals, a mechanical lubricator was developed with a pump having ball checks, the motion of the truck when moving operating the pump. This device was successful but was applied on steel hopper cars, which are used in service was successful but was applied on when tipped allowed the oil to run out of the American Railway Association type of journal boxes used. Il was necessary to remove mechanical lubricator and use the standard method of lubricating with saturated wool waste and oil.

DESIGN OF AXLEBOXES AND CONTAINED PARTS.

Leading engine truck.

In designing these boxes, it was necessary to take care of the vibration of the truck frame in a vertical plane, thus requiring a vertical movement of the box in the truck pedestal jaws, the boxes carrying the weight of the truck by means of equalizers and springs. The fit in the top of the box is shaped so as to receive a plain bearing with a wedge on the top of same, both of which are readily removed. Solid back bearing wedges have now been made standard as it was found that the skeleton back wedge wore very rapidly into the inside of the top of the box and being solid there caused heated journals.

Driving wheels.

The same considerations prevail with regard to driving boxes as with leading truck boxes and therefore substantially the same design of boxes are used.

The sliding fit of the box being re-

lieved on the sides at the top and bottom to permit of locomotive frames assuming an angular position with respect to the center line of the wheels when curving without causing the bearing to bind and heat. The axle loads are much greater than with leading trucks and it is necessary to press the crown bearings in the boxes with considerable pressure, necessitating the use of a much stronger box.

At various times in recent years, improved driving boxes having a crown bearing removable from the box without taking the wheels from under the engine, have been brought out. Four of these have been produced which are worthy of mention; one of these has the crown bearing split in two parts at top center with an adjustable wedge to keep the crown bearing tight in the box. One has a crown brass with an adjustable wedge on one side at the bottom; the third has a crown bearing designed with three parts, the crown section being solid, and the two side sections adjustable by means of X tapered wedge blocks with threaded ends, so that the pound due to wear can be kept out of driving boxes by setting the side sections in as they wear. The fourth which was recently put on the market by the Franklin Railway Supply Company is constructed with a solid bridge of metal across the bottom of the box under the journal, this prevents the closing in of the legs of the box on the cellar, and the giving of a rocking motion to the box on the shoe and wedge. The crown bearing is solid and is inserted on the journal by sliding in by hand and is locked in place with a tapered section with tongues on the side engaging grooves in the body of the box being held securely by wedge blocks with lock nuts. The bottom construction of the box being solid permits of a very lightly constructed cellar being used, which is very easily removed for repacking. Understand this device has been in use experimentally for about two years on one road.

Trailing trucks.

In designing trailing truck boxes, the conditions involved are so different from the cases just mentioned that another type of axlebox is used. In this case, a radial swing truck is necessary with a flexible spring connection to carry the weight back from the driving wheel system. Inside and outside journal trucks are used, the construction of which is familiar to all. Plain bearings and bearing wedges of the same construction as those for cars are used. Both rigid and pedestal type boxes are used.

Passenger and freight cars and tender trucks.

Passenger car trucks are generally constructed so that the boxes vibrate in the truck frames, boxes carrying the weight by means of equalizers and springs, and use pedestal type boxes of various forms. Freight car trucks are generally constructed with the axleboxes rigidly connected as is usually done in the case of arch bar trucks, the weight of the car being transmitted through the truck bolster and springs. In some cases pedestal type trucks are used, especially for passenger engine tenders.

Plain bearings are used in all cases with journal bearing keys to provide a rocking motion for the axles. One patented design of bearing has grooves in the top and on the under side of the top of the box, in which fit four lateral motion rollers fastened together at the ends. These rollers permit of a side movement of the journal in the box.

Design of dust guards.

In the case of leading truck and driving wheel axleboxes, no dust guards can be used as these cellars do not completely encircle the journal, the ends of the bearings being flush with the ends of the boxes. The oil or grease cellars have ends neatly fitted under the journals allowing but 1/8 inch clearance from the same in order to keep out the dirt, etc.

In the case of trailer truck boxes, dust guards are not used but axle opening in back of box is fitted neatly to the axle so that foreign substances are excluded.

On American Railway Association standard journal boxes, such as are used on tender trucks, passenger and freight cars, dust guards which completely encircle the journal are used. These are made of steel, of wood with strips of tin inserted at ends and also of three layers of laminated wood with the grain in the outer layers running at right angles to that in center piece and are cemented together with liquid cement or fastened with wire stitches. Some roads use white canvas duck tacked on inner side of dust guard, with duck slitted at axle opening so that when box is placed on axle it fits around dust guard seat on axle snugly and prevents dust and dirt from working into box from outside. One road uses old plush for the same purpose. Wooden wedges are used in most cases at top of dust guard to close same so no dirt or water can get into box from this point.

On American Railway Association standard journal boxes, lids are also used to prevent water and dust from getting into the box. After considerable experimental work and tests, the following specifications were adopted in 1920 as standard by the American Railway Association.

1. *Scope :*

This specification covers all lids for use on American Railway Association standard journal boxes.

2. *Material :*

Lids may be made of malleable iron or pressed steel. Material to be not less than 3/16 inch in thickness.

3. *Functions :*

a) Lid must protect the journal by preventing the entrance into the journal box of dust, sand, fine coal or other foreign matter;

b) Lid should prevent oil from working out of box.

4. *Construction :*

a) Lid to be attached to the journal box by a suitable fastening so arranged that it can be easily opened and closed, but it must retain itself in a fully open position without danger of closing;

b) When closed the tension between the lid and fastening must be sufficient to prevent vibration of lid or any parts thereof;

c) Lids of the hinged type to have the hinge located at the top of the journal box, so arranged that the lid will open, outward and upward to an angle of 90° with the lid face of the journal box. Lids of other types should provide an equivalent opening;

d) A tight contact between the lid and the face of the journal box must be maintained in order to meet the requirements as stated under item No. 3. For journal boxes used on passenger train equipment, a machined fit is recommended;

e) A ledge, flange, or other suitable arrangement, should be provided on the inside of the lid, particularly along the lower part, so that oil thrown against the inside face will drain back into the box;

f) Springs should be of the coiled type when possible;

g) The eyes of the lid must be integrally closed.

Composition and manufacture of bearings.

With respect to the composition of the metal for the plain bearings used in the axleboxes, there has been quite a large amount of discussion and experimentation with reference to the proper metals and mixtures so as to obtain a bearing metal, working well in the foundry and with a low coefficient of friction while still maintaining slow wearing qualities, not heating very readily and having the requisite strength and toughness to carry the load without distortion, and avoiding excessive breakages of the bearings. Other things being equal, the best bearing metal is that which wears the slowest. The American Railway Association has conducted considerable experiments in this line, and in 1916 adopted as recommended practice, the following specifications which were made standard and later revised in 1920 to the present proportions for phosphor bronze and soft bronze driving box shells, rod bushings and rod brasses for locomotives.

—	Phosphor bronze.	Hard bronze.	Medium bronze.	Soft bronze.
Copper, not over, per cent.	82	80	77	69
Tin, not less, per cent	8	8	7	4
Phosphorus, per cent.	0.4 to 1	0 to 0.1	0.2 to 0.6	...
Lead, per cent.	8 to 13	10 to 15	14 to 20	26 to 33
Other elements and impurities, not over, per cent	1	1	1	1

For lined journal bearings for use on locomotive tenders, passenger and freight cars the following mixtures were adopted as recommended practice being revised in 1920 to the present mixtures.

COMPOSITION OF BACK.	Per cent.	
	Class A.	Class B.
Lead	16 to 24	24 to 30
Tin	5 to 7	4 (Min.)
Total of other impurities (maximum) . .	4	3
Copper	67 to 77	63 to 72

Within the ranges permitted, the tin and lead should vary, if at all, in opposite directions, the tin being increased for the lower percentages of lead.

The owner of the equipment on which the bearings are to be used shall specify which class of metal is desired. If he does not do so, metal of class « A » should be furnished.

COMPOSITION OF LINING.	Per cent.	
	Class C.	Class D.
Tin.	3 to 5	0.5 to 1.5
Antimony	8 to 10	...
Antimony plus tin.	12 to 14	3 to 5
Arsenic (maxim.)	0.2	...
Total of other impurities (maxim.).	0.5	0.5
Lead	85 to 88	94 to 96

Metal of class « C » is for linings of a nominal thickness over 1/8 inch.

Metal of class « D » is for linings of 1/8 inch or less in nominal thickness. This classification is independent of the composition of the back. Either composition of the back may be used with the composition of lining specified for the thickness of journal lining which is ordered.

The majority of the railroads in the United States use these formulae with variations to suit individual preferences or needs. Some using phosphor bronze for locomotive and car bearings, others using it only for locomotive bearings while others use none at all. When phosphorus is used it produces a much better and closer grade of metal with a less tendency to blow holes and improving the casting both in strength and ductility. It was later found that in a copper tin alloy arsenic practically has the same effect as phosphorus and experiments have been conducted which showed this composition to have as good wearing qualities. It has also been found that if the proportion of lead is increased up to a 15 % limit and arsenic or phosphorus left out, the durability is still further increased. For lining metals, it has also been found that antimony which is an invaluable ingredient for hardness must not be over 18 % of the mixture or it will become too brittle.

Manufacture.

Before lining, the brass backs shall be bored and thoroughly tinned in accordance with the best standard practice. The thickness of linings which is desired in the order shall be specified. If it is not specified, linings one-quarter inch thick shall be furnished. After lining, the ends of the bearings shall be made smooth by scraping, filing or machining. They must not be ground or rubbed with abrasive materials.

Great care must be used in the manufacture of journal bearings to see that a proper union is secured between the back and the lining metal, for a loose lining will produce a heated journal invariably by allowing the lining to turn out of place. The practice in most railroad shops is to heat the bearing, then thoroughly clean it with a solution containing dilute hydrochloric acid and zinc, then dip it into a bath of molten zinc, and while still hot clamp it to a mandrel and pour the lining metal. Some roads clean brasses with a solution of sal ammoniac, and tin by rubbing with a stick of solder before pouring. After cooling the projecting edges are trimmed off and the bearing is ready for boring to size, and application to the journal. In relining bearings, it is very necessary to thoroughly clean the metal before tinning in order to secure a tight lining; and in some cases it has been found necessary to bore a light skim of metal out of the bearing, in order to have a new surface on which to reline the bearing in order to avoid loose linings, other railroads are able to secure tight linings on the old surface of the bearing.

Some very complete tests have been run on one railroad which demonstrated that there is no difference in the running qualities or temperature of a bearing which had been bored or broached to fit the journal and one which had been properly filed or scraped to fit the journal.

In the manufacture of crown bearings for driving boxes, these are generally pressed into the box at a given pressure depending upon the journal diameter. In most cases crown bearings are turned with a shoulder at the outer end which rests against the box, and this practice has been very beneficial in prevention of loose bearings in the boxes. After

pressing in box, holes are drilled through bearing and tapered pins fitted to same and driven in from the inside to further assist in keeping the bearing tight in the box.

In a majority of cases railroad practice when using grease lubrication is to bore the crown bearings to a size 1/100 inch large for all journals other than main. Main journals in some cases are also bored 1/100 inch larger than journal; and in other cases to neat size of journal and then scraped to fit. It has also been found beneficial to counterbore the top of the crown bearing in the main box to a width of 3 inches to 3 1/2 inches and about 3/8 inch deep leaving a bridge of solid metal at either end of the bearing, to prevent the grease working out. This practice tends to make the journal wear up into the box and reduces the tendency to pound making it possible to increase the length of time in service before it is necessary to drop the main wheels for pound in boxes. It has also been found beneficial in reducing the pound to extend the crown bearings on the main boxes of modern locomotives considerably below the journal center and then relieve the bearing to the center line of the journal giving approximately an arc of contact of the bearing with the journal of 180°.

Limits of wear, axles and bearings.

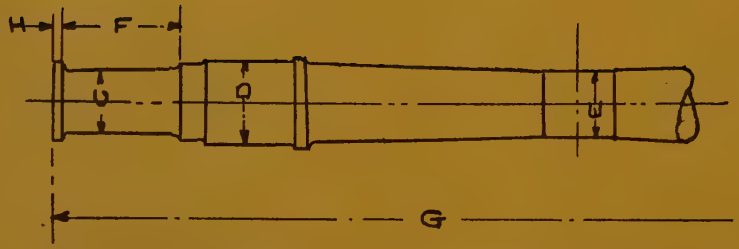
The limits of wear of both driving, leading, trailing and tender truck and car axles have been practically determined by the Interstate Commerce Commission Rules for the Inspection of Locomotives and Tenders, which state that driving, trailing and engine truck axles with any of the following defects shall not be continued in service. « Bent axle, cut journals that can not be made to run cool without turning seamy journals in steel axles, transverse seams in iron axles, or any seams in iron axles causing journals to run hot; or unsafe on account of usage, accident or derailment; driving, trailing or engine truck axles more than 1/2 inch under original diameter except for locomotives having all driving axles of the same diameter, when other than main driving axles may be worn 3/4 inch below the original diameter. »

For tender truck axles, the minimum diameters of axles for various loads shall be as follows :

Axle load.	Minimum diameter of journal.	Minimum diameter of wheel seat.	Minimum diameter of center.
50 000 lb.	5 1/2 in.	7 3/8 in.	6 7/16 in.
38 000 lb.	5 inches.	6 3/4 in.	5 7/8 in.
31 000 lb.	4 1/2 in.	6 1/4 in.	5 5/16 in.
22 000 lb.	3 3/4 in.	5 inches.	4 3/8 in.
15 000 lb.	3 1/4 in.	4 5/8 in.	3 7/8 in.

Tender truck axles with any of the following defects shall not be continued in service. « Bent axle, cut journals that can not be made to run cool without turning, seamy journals in steel axles, or transverse seams in journals of iron axles, or unsafe on account of usage, accident or derailment; collars broken or worn to 1/4 inch or less in thickness; fillet in back shoulder worn out. »

The American Railway Association Rules of Interchange, effective 1 January 1924 call for axles to be removed, owner's responsibility when broken or having seamy journals; fillets at back end of journals less than 1/8 inch radius on axles of 40 000 lb. capacity, less than 5/16 inch radius on axles of 50 000 lb.



A. R. A. designation of axle.	Size of journal.	Load designed for	Total weight on rail.	Nominal capacity.	Limits of wear					Dimensions, new					
					C	D	E	F	H	C	D	E	F	G	H
	Inches.	Lb.	Lb.	Lb.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
A	3 3/4" × 7"	15 000	66 000	40 000	3 1/4	4 7/8	4 3/16	7 1/2	1/4	3 3/4	5 1/8	4 1/4	7	6-11 1/4	5/8
B	4 1/4" × 8"	22 000	103 000	60 000	3 3/4	5 1/2	4 11/16	8 1/2	1/4	4 1/4	5 3/4	4 3/4	8	7-0 1/4	5/8
C	5" × 9"	31 000	140 000	80 000	4 1/2	6 1/4	5 1/4	9 1/2	1/4	5	6 1/2	5 3/8	9	7-2 1/2	3/4
D	5 1/2" × 10"	40 000	169 000	100 000	5	6 3/4	5 3/4	10 1/2	1/4	5 1/2	7	5 7/8	10	7-4 1/2	3/4
E	6" × 11"	50 000	210 000	140 000	5 1/2	7 3/8	6 5/16	11 1/2	1/4	6	7 5/8	6 7/16	11	7-6 3/4	7/8
F	6 1/2" × 12"	60 000	...	...	6	8	6 3/4	12 1/2	1/4	6 1/2	8 1/4	6 7/8	12	7-8 3/4	7/8

Fig. 6. — American Railway Association standard axles. — Limits of wear and new dimensions.

and 60 000 lb. capacity and less than 3/8 inch radius on axles of greater capacity; length of journal increased 1/2 inch over standard or collar broken or worn to 1/4 inch in thickness or less.

The total weight of car and its lading must not exceed weight given in column « A », column « B » is the nominal capacity stenciled on all cars. Axles must be removed from service when less than the prescribed limits, in columns « C », « D » and « E » or when the condemning limits in columns « F » and « H » are reached. (See fig. 6.)

For cars, journal bearings are removed when lining metal is worn through or is worn to such an extent that it will wear through before time of next periodical inspection; when bearing is cracked through or lining loose. Some railroads have definite limits for removal; thickness at crown to be not less than 3/4 inch for 3 3/4 inches × 7 inches, 4 1/4 inches × 8 inches, 5 inches × 9 inches and 5 1/2 inches × 10 inches while for 6 inches × 11 inches 7/8 inch thickness is allowed.

For locomotives, the determining factor for removal is the thickness of metal left at the crown of the bearing. Some roads feel that one thickness at crown is the correct measuring stick for all locomotives irrespective of weight, while others feel that the thickness should be graduated according to size of journal and axle load which would appear to be the correct theory. The general shop practice is when locomotives are in shop for class repairs, to renew bearings if they will not rebore to a thickness of 1/4 inch above minimum limit. For trailer bearings, if not removed when lining is worn out, which is generally the case, the minimum thickness allowable at crown is usually not less than 1 5/16 inches.

Bearing pressures per square inch projected area.

Some years ago before the advent of the modern locomotive and car, in general practice the following were considered as safe allowances in the different classes of service for weight in pounds per square inch of projected area of the journal.

Engine truck journals, passenger locomotives	160 lb.
Driving and trailing journals, passenger locomotives	180 lb.
Driving, engine and trailing truck journals, freight and switch locomotives	200 lb.
Tender, passenger and freight car journals	300 lb.

Other authorities quoted as allowable pressures, the following as stated.

Driving wheel journals	Up to 556 lb. per square inch.
Car axle bearings	300 to 325 — — —
Tender axle bearings	Up to 425 — — —

With the necessity for a heavier locomotive and increased hauling capacity, axle loads up to 65 000 lb. have been used quite often and higher pressures per square inch of projected area have been found necessary until now bearing pressures as follows are found to be in use.

Leading trucks	Up to 234 lb. per square inch.
Driving wheels	— 258 — — —

Trailing wheels	—	298 lb. per square inch.
Tender wheels	—	561 — — —
Freight car wheels	—	563 — — —
Passenger car wheels	—	496 — — —

The above being the case, much more care must be used in the selection of a proper lubricant and more careful attention must be given to keep them from running warm.

Choice of lubricants and manner of application.

For engine trucks, trailing trucks, tender and car trucks, car oil is in general use applied with wool waste, cotton waste with brass springs in same or plain cotton waste as the medium through which oil is transmitted to the journal from the cellar under the journal. Waste being loosened, covered with oil and soaked for forty-eight hours in soaking vat at a temperature of 70° F. so as to thoroughly impregnate the threads with oil. When ready to use, packing is either drained or pressed out until the proper oil content remains which is approximately three to four pints of oil to one pound of dry waste. The packing will then be found to be in a resilient or elastic condition.

With reference to the manner of applying the packing, same as adopted by the American Railway Association in 1920 as the Standard Method of Packing Journal Boxes calls for packing to be applied in three sections. First, the inner section twist somewhat tightly a rope of packing and place in the extreme back section of the box, making sure that it is well up against the journal so as to properly lubricate the fillet on the journal and keep out the dust and keep in the oil.

Second, the main section, apply sufficient packing (preferably in as few pieces as possible; two or not more than three) to fill the space behind the collar. Care should be taken to have the packing bear evenly along full length of lower half of journal. The packing should not be too tight (causing it to glaze over and heat) but it should be tight enough to overcome any tendency to settle away from the journal. The packing should extend to approximately the center line of the journal but not above at any point, and should be pressed down evenly at sides so that no loose ends may work up under the journal bearings, and cause a waste grab or hot box.

Third, the outer section, a third piece of firmly twisted packing should be placed in front of the journal and extending up only to touch the bottom of the journal collar to prevent the displacement of the main packing. No loose ends of packing should be allowed to hang out of the box as they tend to syphon out the oil.

For driving wheels, both soaked waste as above and a hard grease known as driving journal compound are used as lubricating mediums. Oil lubrication being used almost exclusively on the lighter power, and on locomotives in switching service. Oil is applied to the journal through the medium of soaked waste as above, while the grease is applied in cakes the shape of the journal and cellar, with a perforated plate, having the exact contour of the journal between the grease and the journal. Cake of grease is pressed against journal by a flat metal plate under same with a coil spring resting on the bottom of the cellar.

The journal depends upon the heat generated during motion to soften the grease and the turning motion of the journal draws it through the perforated plate, and on the journal. On account of the comparatively slow movement of engines engaged in helping and switching service, the journal heat developed is not as great as in road service and the grease is not softened to as great an extent, consequently the perforated plate has 3/8 inch holes placed in same as against 3/16 inch holes in road engines screens; so as to permit of a freer feed to the journal. In general if all the grease is drawn from the boxes about every thirty days, perforated plates thoroughly cleaned and boxes repacked, no trouble will be experienced with switching locomotives. One road uses a special soft grease in these engines.

In driving boxes fitted with oil lubrication, two holes are generally provided from the cavity on top of the box to the journal to give an auxiliary top feed from the saturated waste placed in the afore-mentioned cavity. Engineer when oiling around at stops drops a few drops of oil in same.

Engine trucks and trailer truck boxes are generally provided with oil holes through the top of the bearing and with an oil cup or funnel for the engineer to fill as he passes in oiling. With deep truck cellars, it is very necessary to have an auxiliary top feed, and for the engineer to drop a small quantity of oil in same before starting from the shop; because if this is not done, the capillarity of the packing will not be great enough to draw oil to the journal before the engine attains a speed of perhaps forty or fifty miles an hour.

Experiments with different mixtures of packing, that is cotton and wool threads, have shown that a mixture of 70 parts wool and 30 parts cotton gives the best results. The capillarity of cotton is superior to wool but it does not have the resiliency of wool; such being the case, brass spiral springs about 1 inch outside diameter and 2 inches long to the number of from 10 to 14 per pound, are added to the dry waste to give it the resiliency of wool threads which are becoming scarcer due to improved processes used in woolen mills, recarding and utilizing much that was formerly wasted.

The oils used are, generally speaking, mineral oil with a lead soap base, and are varied in composition for summer and winter use. In some cases, summer oils have a certain percentage of cylinder oil stock petroleum oil mixed in with the base oil. In other cases, crude petroleum or well oil is used as it comes from the ground, while in other cases, mineral oil used with about 2 % of rape oil is used.

The hard grease used from driving boxes consists of well refined cylinder oil stock petroleum oil, soda soap made from a good grade of hard tallow and not less than 0.5 %, nor more than 2.5 % free alkali, calculated as NaOH. The total water, glycerine and impurities present should not exceed 1/3 of the dry soap content. Some driving journal compounds contain nothing but the soda soap and cylinder oil stock; these are not as hard as those containing alkali and do not heat to as high a temperature in service but being softer waste away more quickly and can not be reclaimed as readily.

Packing reclamation.

Well thought out systems of handling have been devised for the reclamation of both oil packing and driving journal

compound, so that satisfactory service is obtained from the use of same.

In the case of oil, the packing is drawn direct from the journal boxes into pails, care being taken to see that it does not touch the ground. There are two systems of reclaiming in general use for oil packing in this country; one being known as the « hot oil » process while the other uses centrifugal machines for extracting the oil from the packing and for filtering the oil.

In the « hot oil » process, when the packing arrives at the reclamation plant, it is first placed in a vat with steam heated coils around same so as to heat the oil and to drain as much of it out of the packing as possible. It should then be placed on a netting picking table with meshes preferably not less than 3/4 inch square, and hard knots picked out. It is shaken over the netting in order to knock out dirt, pieces of babbitt, etc. From the picking table it passes to the double washing vat, where it is allowed to lay in hot oil in vat No. 1 for a few minutes and is stirred thoroughly with a small pitch fork to loosen the dirt thoroughly and is pressed out under press with netting basket. It is then passed through the other vat, or No. 2 in the same manner and again squeezed out; it is then ready to be resaturated. When resaturating it may be used in its entirety or mixed with a certain percentage of new waste. The washing vat is provided with a netting screen about 6 inches from the bottom and should be cleaned out after each seventy-two hours of use. Oil is passed through a filter and used again. Lining metal is reclaimed from the scrap and short ends picked out and returned for credit and re-use.

With the use of a centrifugal machine, the oil is first extracted from the waste, and the waste dried, and the oil filtered in another centrifugal machine. Although some of the later designs of machines perform both operations at the same time. The cleaned waste is then picked over for short ends, large pieces of babbitt, dirt, etc. It is then ready for resaturating in a soaking vat in the ordinary manner, and handling the same as with new packing.

There is one company in the United States which does this work under contract using the centrifugal method; a certain figure being charged for each pound only saturated, and another figure for each pound of packing reclaimed and made ready for use. These unit costs include unloading of old waste to be reclaimed, reclaiming resaturating, placing in cans and shipping to points desired.

The equipment and plant is owned and operated by the waste reclaiming company and no initial capital investment outlay is necessary by the railroad company contracting. Plants are placed in central locations to take care of points within a radius of 150 to 200 miles in all directions. After a certain time has elapsed, the railroad company is privileged to purchase these plants if it so desires. The results derived from these plants have been very good in some cases, but this industry is comparatively new as yet.

In these plants the equipment is all electric driven. Old waste comes in at one end, is placed in two hot oil tanks for about five minutes to loosen up the packing, and make it more fluid. It is then placed on draining boards and allowed to drain out for about five minutes. It is then placed in a centrifugal extractor where the oil is extracted from the waste and filtered. The waste is then placed in a mechanical cleaner which is a large cylindrical receptacle

of 7/8 inch mesh wire screen, having an oscillating motion with a blast of hot air through cylinder. The refuse falls to the bottom of the cleaner and is forced out by the air blast to another receptacle. The effect of the hot air is to remove all dirt and short ends and dry out the moisture. Waste is then placed in impregnator, which is cylindrical in form and has an oscillating motion where a pre-determined amount of oil is put entirely through and into the waste fibres. This amount of oil can be varied as desired. Packing is now ready for shipment. Rolls are also made and prepared for use in back of boxes.

Driving journal compound to be reclaimed is drawn from cellars direct into buckets or other receptacles and kept free from dirt as possible. Dry and burnt grease and cuttings is separated from that which is still good and thrown away. The remainder is passed through a perforated plate having 1/2 inch holes in same about 3/4 inch centers two or three times as may be found necessary to still further clean and mix the grease. It is then pressed into cakes and re-used on all except passenger driving boxes. Some roads use the reclaimed grease only for switching locomotives. Other roads use it in local passenger locomotives.

Grease is also reclaimed by melting and boiling and adding the necessary ingredients to bring it back to the original composition, but in most cases the resulting product was too soft to be used over again, and this reclaiming process has been practically abandoned.

Cost and performance of lubricants.

A large number of the railroads of the United States purchase their lubrication under guarantee contract system from various oil companies. The oil company guaranteeing the performance of its products to be such that it will not cost more than a certain figure to lubricate locomotives and tenders per 1 000 miles run; and another figure to lubricate freight cars per 1 000 miles run and still another figure to lubricate passenger cars per 1 000 miles run. Should these figures be exceeded, the oil company loses the amount required over the guaranteed cost. The oil company furnishes, one or more service engineers to look after their products, and the railroad company agrees to cooperate with these engineers, and to save as much waste as possible. Under this system lubricating oils and greases are not purchased under specification by the railroad companies.

Practically all railroads in the United States keep lubrication records in the form of miles per pint or per pound for each lubricant used on the engine or car. Mileages on locomotives as high as 45 miles per pint of car oil are reported. This includes the engineers allowance for oiling motion gear, leading, trailing trucks. For driving journal compound as high as 400 miles per pound have been reported. This of course for ordinary locomotives only; for *Mallet* locomotives, these figures would be reduced at least one-half.

With reference to the amount of lubricants used per 100 journal miles the best performances reported are for oil 0.00124 pint, and for driving journal compound 0.00044 pound. For freight cars, 725 miles per pint, and 0.00124 pint per 100 journal miles. For passenger cars, 510 miles per pint, and 0.00124 pint per 100 journal miles.

Referring to number of heated journals; the statistics covering these figures are made up in so many different ways

that comparisons are not very readily made.

Average miles per locomotive hot box for seven railroads . . . . . 82 707 miles.
Minimum 27 500 miles, maximum 169 111 miles.

Average miles freight cars per heated journal for eight railroads . . . . . 68 569 —
Minimum 15 368 miles maximum 300 000 miles.

Average miles per passenger car heated journal for six railroads . . . . 556 210 —
Minimum 209 838 miles, maximum 1 116 234 miles.

Of the total number of heated journals accruing in all classes of service reports from three railroads indicate these bear the following relations.

	Per cent.
Engine trucks	0.247
Driving wheels	0.197
Trailing trucks	0.024
Tender trucks	0.0945
Freight cars	97.94
Passenger cars	0.8492

Reports from four railroads indicate that heated bearings on locomotives only bear the following relations.

	Per cent.
Engine trucks.	31.99
Driving wheels	41.16
Trailing trucks	8.50
Tender trucks	18.35

Of the heated bearings occurring on locomotives on some of the railroads, the driving boxes far outnumber those occurring on the leading, trailing or tender trucks individually, but in general the far greater number of hot boxes occur on leading trucks; due not in all cases to faulty lubrication, but loss and breakage of oil cellars, sometimes caused by poor workmanship but oftener by poor design.

Reports from two railroads indicate that percentage of heated journals occurring compared with total number of journals in service runs as follows :

	Per cent.
Engine trucks	3.45
Driving wheels	0.865
Trailing trucks	2.52
Tender trucks.	1.30

No bonuses for oil economies are paid on North American Railroads but two South American roads report bonuses paid for these savings as follows :

One pays no bonus, but fines may be applied for excess consumption.

One reports a fixed bonus paid which varies according to the grading of the engineer, and covers economy in lubricating oils, materials and fuel taken together.